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EDITORIAL.

Title of Journal.

As a result of a decision of the Board, the Quarterly Journal will, in future, contain only the results of investigations carried out by members of the staff or articles containing the results of investigations specially contributed and approved by the Editorial Committee, such as the article contained in this issue by Dr. Chittenden, Botanist of Prang Besar Estate.

All abstracts or reviews of investigations carried out in relation to rubber cultivation, preparation, diseases, etc., in other rubber producing countries will be published in the Malayan Agricultural Journal.

Since the inclusion only of articles containing the results of researches or investigations carried out by the staff of the Institute may render it impossible to issue the journal at quarterly intervals, it has been decided to change the title from "Quarterly Journal" to "Journal of the Rubber Research Institute" and to issue numbers as and when material for publication becomes available.

It is hoped, however, to maintain the issues at approximately quarterly intervals, even if each number is reduced in size and contains a smaller number of contributions.

The present issue, therefore, constitutes the first number of Volume 3, and, although published somewhat late in the present year, for which there are adequate and reasonable excuses, it is anticipated that at least two, if not three, further numbers will be issued by the end of the current year.

Biological Aspects of Soil Fertility.

The article by Dr. Corbet, Bacteriologist, entitled "A Bacteriological Study of the Decomposition of Soil Organic Matter and its Bearing on the question of Manuring" is of considerable interest and value as a preliminary contribution to an important scientific problem. If the results obtained are confirmed by further experimental data, this method of investigation should prove very valuable in indicating the fertility requirements of soils. As is well known, the present methods of chemical investigation leave much to be desired in this respect. The figures provided by such analyses of soils in temperate regions cannot be applied to those in tropical regions where the biological conditions affecting the availability of plant constituents in the soil are much more active and are very different to those which exist in soils in colder climates. The importance of the content of humus (organic

matter) in the soil, especially in relation to permanent crops such as rubber, has already been indicated by the Soils Division and evidence is accumulating as to the value not only of green manuring and the cultivation of leguminous cover crops, but also of selective weeding and the establishment of a suitable secondary "jungle" growth on rubber areas. Such methods are closely related to and have an important influence on the biological activity of the soil and the maintenance of a satisfactory balance of humus and nitrogen in the soil.

Effect of Covers and Clearing Methods on the Growth of Young Rubber Trees.

In view of the great interest which is being taken during recent years in the use of cover crops and selective weeding for the maintenance of soil fertility on rubber estates and also as a first line of defence against soil erosion, particularly on hilly and undulating areas, a series of plots were laid down at the Experiment Station, Sungei Buloh, by Dr. Weir (late Head of the Pathological Division) in order to obtain definite measurements of the effects of such treatment versus clean weeding. On some plots also, all surface timber was left, with the two-fold object of providing partial shade for the soil and the slow addition of plant nutrients to the soil from the decay of the timber.

Various methods of planting, including seed-at-stake, basket plants and stumps were employed, in order to ascertain also whether the treatments had a different effect on the various types of planting material due to a possible varying development of root growth.

The first records of height and girth measurements were taken last year and these have been analysed statistically and are discussed in a paper under the above title in this journal by Mr. A. R. Sanderson and Dr. W. B. Haines. It has been generally held that cover plants definitely retard the growth of rubber trees during the early stages of growth, but no figures have been published to support this opinion.

The figures now published indicate definitely that such a retardation in growth does occur.

It must, however, be clearly understood that this applies, as far as these results are concerned, only to young rubber and there is reason to believe that eventually the trees under cover crops will catch up in growth those which have been kept clean weeded.

The advantage in growth in the young stage is probably obtained at the expense of a more rapid deterioration of the soil.

The effect of leaving surface timber on the land has proved definitely beneficial.

The plots planted under "Kampong" (Small-holdings) conditions, in which secondary jungle growth (belukar) is allowed to establish itself, keeping only a narrow area renticed on each side of the rows of trees, have so far compared favourably with the plots under other treatments. Evidence is accumulating from other sources that the rubber plants on such areas may eventually show an advantage in growth due to the maintenance of soil fertility, particularly in relation to humus content of the soil.

Another interesting feature which is illustrated is the effect of drought on growth, especially with rubber plants of a certain stage of growth, which is probably related to the development of the root system. This feature has been noted on other experimental plots at the Station.

Wound Protection in Budding Operations.

Recent investigations by the Pathological Division of the Institute (See Quarterly Journal Vol. 2, No. 3, p. 113) have drawn attention to the value of a Bitumen or Asphalt-Kerosene mixture as a wound dressing for cut or broken surfaces of trees, caused by windbreak or pruning.

The article by Messrs. Mann and Sharples in this journal draws particular attention to an important aspect of this problem in the treatment of cuts made by pruning in the budding of rubber plants, especially when the budding is carried out on 2-3 years old stock. In view of the cost and the value of budded plants, it is imperative to pay careful attention to the satisfactory treatment of cuts by the application of suitable wound dressings in the case of such material, in order to avoid loss of valuable plants due to the entrance of various fungi, through the cut surfaces, which as is shown, may penetrate sufficiently far to destroy the plant.

If the instructions laid down in this atricle are followed carefully, there should be little or no loss caused by the entrance of fungi which produce this die-back.

The Tapping of Budded Rubber.

The article by Dr. R. J. Chittenden, the Botanical Officer attached to the well known Prang Besar Estate, contains further results on the Heusser System of Double Tapping consisting of two stepped or echelon cuts on budded rubber trees. The results confirm those previously published by Dr. Heusser, Botanist of the

A.V.R.O.S. Proefstation, Sumatra, and show that the yield of budded rubber can be increased considerably by this method of tapping. It is perhaps too early to state whether the method is applicable to all clones in relation to the possibility of development of Brown Bast, but apart from this, the system may prove of considerable economic value in the tapping of budded rubber trees.

Planting Systems for Budded Trees.

An article by Mr. C. E. T. Mann, sets forth the pros and cons of three systems of planting of budded rubber trees, viz. (a) block or mono-clone planting, that is, the planting of a single "proved" clone over a definite area, (b) mixed planting of a proved clone with one or more promising clones having shorter records of yield, (c) mixed planting of a number of clones.

For various reasons set forth in this article, block or mono-clone planting is considered desirable. It is well known that several companies have already adopted this system on large areas and during the last year an increasing number of estates have followed the same procedure.

A BACTERIOLOGICAL STUDY OF THE DECOMPOSITION OF SOIL ORGANIC MATTER AND ITS BEARING ON THE QUESTION OF MANURING.

BY

A. S. Corbet.

Introduction.

In the present paper an account is given of some experimental work concerned with the evolution of carbon dioxide from soils. This work forms part of a general investigation of certain aspects of tropical soil microbiology and, although considerably more data are required before any degree of completeness is reached, the results obtained to date with the work on carbon dioxide evolution has been sufficiently definite to be placed on record.

The literature contains so many papers cognate to the subject that it is out of the question to do more than refer to some of the outstanding reports of work by previous investigators. Most of the papers are of comparatively recent date but as long ago as 1905 Stoklasa and Ernest (1) showed that valuable information concerning the activities of soil micro-organisms is obtained by measurement of the carbon dioxide evolution from soils.

Russell and Appleyard (2) studied the composition of soil gases and showed that a relation existed between the numbers of bacteria present, the carbon dioxide production and nitrate formation in soils. Carbon dioxide production from soils containing pure cultures of single species of organisms had been investigated by Waksman and Starkey (3) who found that, under such conditions, the gas evolution varied not only with the species of organism employed but with the amount and availability of the organic matter present in the soil.

The formation of carbon dioxide in soil and in soil with added organic matter, such as straw and stable manure, was studied by Lemmermann and Weissmann (4) who determined the daily yield of carbon dioxide for a period of nearly 3 years. The curves thus obtained resemble those shown in Figure I in this paper and the authors deduced an equation which accurately expressed their results.

The question of the decline in the rate of carbon dioxide evolution which occurs when soil is subjected to laboratory conditions was examined in some detail by Bal (5) who showed that is was due neither to exhaustion of the supply of organic matter nor to the formation of toxic bodies.

The direct determination of carbon dioxide production from soil in the field is a matter of considerable difficulty but it is important to know how closely results found in the laboratory agree wtih those obtained from soil *in situ*. In a recent paper Humfeld (6) has described a new method of making field determinations of carbon dioxide from soil and has summarised the procedures adopted by previous authors.

An account of work on the respiration and bacterial activity of forest soils has been published by Fehér (7) who has shown that a close relationship exists between the aerobic bacterial content and the carbon dioxide production of such soils.

Little information is available concerning the bacterial population of tropical soils. To some extent this is surprising, for the importance of biological factors when dealing with soil problems need hardly be stressed. It is known from work on soils in temperate regions that most agricultural operations are closely correlated with changes in the soil flora and fauna; but it is debatable how much weight can be placed on results obtained in temperate zones when dealing with tropical soil problems.

The question of manuring is related not only to the effect of the fertiliser as a plant food constituent but is dependent also to a great extent on the chemical effects produced on the soil bacteria and the decomposition of humus effected by such organisms. Thus, when considering perennial crops such as rubber, in which crop returns may be expected to be delayed, it is particularly important to be in a position to appreciate any marked changes in the bacterial population of the soil at the outset before embarking upon a lengthy or costly programme of manuring.

In the present paper an account is given of some preliminary work on the bacteriology of soils in Malaya and a method of estimating soil fertility is described which appears to give more conclusive results than any in vogue at present.

The Bacterial Population of Malayan Soils.

During the past two years, soil samples from selected sites have een submitted to bacteriological examination at weekly intervals. The samples were obtained from the Sungei Buloh Forest Reserve where the soil comprises a sandy layer of variable depth overlying a white clay subsoil. The specimens examined fall into three categories :

(a) those taken from soil under primary jungle;

(b) those taken from the Institute's Experiment Station in the centre of the Sungei Buloh Forest Reserve. Bacterial

counts of this soil have been made at regular intervals for two years during which period the operations of felling, clearing and burning were carried out. At the time of writing and for the past year a cover of *Centrosema pubescens* has been growing;

(c) those taken from soil under mature rubber on a neighbouring estate.

In the case of (b) two samples were taken weekly from one small area (about 600 square feet) in Block 15.

The usual plating method of analysis was adopted, Thornton's agar (8) being employed as the nutrient medium, and the samples were examined precisely 24 hours after removal from the field. This last point is of some importance as it was found that a diminution in bacterial numbers occurred with the lapse of time.

To some extent, the results of the plate counts are unexpected. It might be imagined that, in a tropical country, in which plant and animal life abound, the soil would support a teeming population of micro-organisms. The reverse, however, was found to be the case. In England from 5 to 20 millions of bacteria may be expected in 1 gram of ordinary soil. In the samples taken at Sungei Buloh, the total number of organisms found by the plating method rarely exceeded 1 million per gram of soil. Moreover, almost invariably, the numbers of fungus colonies on the plates exceeded those of the bacteria and this was particularly the case with jungle soils.

In general, the numbers of soil micro-organisms found per gram of soil were consistently low (the average value being under 1 million) and varied but little with the source of the sample. The predominance of fungi on the plates was striking; it indicates that these organisms play an important role in the decomposition of soil organic matter. Waksman and Heukelekian (9) have already shown that soil fungi are able to decompose rapidly almost all the constituents of soil organic matter. The soils examined all possess a *p*H value under 7.0 so that local conditions favour the development of fungi rather than of bacteria. During the two years that the soil on the Experiment Station site has been under observation, the original jungle has been felled and burnt and the site planted with rubber seedlings and *Centrosema pubescens*. Throughout this period the plate counts have been low with the exception that, after burning operations on or near the site, large increases in the micro-organic population were observed. The highest figure found was 17 million organisms per gram of soil and this was obtained when burning operations has been in progress almost continually for 3 or 4 weeks over the area containing the site from which the soil sample was procured. This increase in plate counts was transitory and the normal low numbers were found 3 or 4 weeks after the cessation of burning operations.

Soil samples from primary jungle and from rubber estates gave plate counts of the same order as those from the Institute's Experiment Station.

The Evolution of Carbon Dioxide from the Soil.

The fertility of a soil, as the term is usually understood, is largely dependent on the rate of decomposition of the organic matter present. This decomposition is effected by the action of bacteria and fungi, and depends not only upon the concentration of micro-organisms present, but also upon other factors, such as the amount and availability of organic matter, the state of division of the soil particles, their physical state, the aeration of the soil, its moisture content and other subsidiary conditions. All these factors contribute to the direct cause of decomposition, namely the concentration of micro-organisms, which is generally assumed to be the maximum which the soil can support under existing conditions.

This assumption has led to the means of assessing soil fertility known as the method of bacterial counts.

This method is at best a very arbitrary one, as only a proportion of the species of bacteria present will grow under the conditions of analysis, and variable factors such as "spreading" fungi may impede the development even of these. Moreover, even an accurate count of all the micro-organisms present would not be a measure of their activity in decomposing organic matter.

The decomposition of soil organic matter involves a proportionate evolution of carbon dioxide, and if the rate of this evolution be measured, a much more complete index is obtained of biological activity in the soil and therefore of soil fertility. To this method it has been objected that the observed falling off in the evolution of carbon dioxide when a soil is subjected to laboratory treatment indicates a departure from natural conditions which largely invalidates the method as a means of comparing the biological activities of different soils. It is true that when a soil is taken from the field and placed in the laboratory, a period of adjustment follows before equilibrium is attained; but it will be shown in this paper that after a short initial period, the relationship between the rates of gas evolution of similar soils differently treated remains constant: it is unaffected by the lapse of time or by further subjection to laboratory conditions. Therefore, for purposes of comparison the method of carbon dioxide evolution is justified.

In the laboratory the usual method of estimating the carbon dioxide of soil decomposition consists essentially of passing a continuous current of carbon dioxide-free air over soil contained in a flask, and absorbing the carbon dioxide liberated in solutions of

standard alkalinity. At regular intervals the gas absorption tubes are changed and the carbon dioxide is estimated by acid titration. In such experiments it is found that, although at first the evolution of carbon dioxide proceeds rapidly, a decline eventually sets in, for which no satisfactory explanation has yet been advanced. In the present paper experiments are described which show that although this decline in gas evolution is steadily maintained in a number of soils under comparison, it does not disturb the ratio of the velocities of carbon dioxide production in the various soils; and it, therefore, has no effect upon the use of this method for the *comparison* of soil fertility.

Experimental.

The method used for estimating the carbon dioxide evolved by soil samples differed in no essential respect from that adopted by previous investigators such as Lemmermann and Weissmann. A weighed amount of soil was placed in a conical flask and, at intervals of 2—4 days, the gas evolved was swept by a current of dry carbon dioxide-free air into a series of absorption tubes containing standard sodium hydroxide solution. It was not practicable to have a slow continuous current of air passing over the soil throughout the experiment although such an arrangement would have been preferable. During the longer experiments a small flask containing a 12 per cent. (by volume) aqueous solution of sulphuric acid was interposed between the drying apparatus and the soil flask. This arrangement served to keep the soil at constant humidity, but was dispensed with during the shorter runs in which the loss of moisture by evaporation was inappreciable. The carbon dioxide absorbed by the caustic soda was determined by titration with standard acid in presence of barium chloride and phenolphthalein.

Five of the first six soil samples examined had the same origin, viz. Sungei Buloh in the State of Selangor, F.M.S., where the soil comprises a top sandy layer overlying a white clay subsoil.

The first sample examined (A) was jungle soil from the Sungei Buloh Forest Reserve and the results obtained (Table 1 and Figure 1) call for no special comment. A decline in carbon dioxide production was evident after the first week, and for a further 40 days a small but regular decrease in the rate of gas evolution was observed.

Other samples were obtained from the Institute's Experiment Station situated in the centre of the Sungei Buloh Forest Reserve, and these were taken from Block 15 where the jungle had been felled and cleared about a year previously, the soil having been fallow for this period. One sample was air-dried and then divided into two parts and water added to the extent of 2.9 (B) and 12.9 (C) per cent. respectively. The curves obtained for samples B and C show

that the variation in gas evolution consequent upon different water contents was not striking.

A further sample from Block 15 was air-dried, then two portions were sterilised in an autoclave by heating at 15 lbs. pressure (120.5° C.) for 30 minutes on 3 successive days. Water was added to each sample to the extent of 3 per cent. and then the samples were inoculated with pure cultures of a soil *Micrococcus* (D) and a species of *Actinomyces* (E) respectively. The *Actinomyces* soil gave the lower yield of carbon dioxide throughout. Pure cultures of the respective organisms were obtained from these soil samples at the conclusion of the experiment.

An experiment was carried out with a peaty soil under rubber cultivation (P) which had received a dressing of lime some 3 years previously. This experiment was continued for several months and the results are expressed graphically in Figure 2. After 56 days the soil was well shaken and the air, instead of being passed over the surface of the soil, was introduced through an inlet tube opening well under the surface; subsequent readings showed that this procedure had no effect upon the retardation of gas production .

All the experiments were carried out at laboratory temperature which remained fairly constant, ranging between 26° and 29° C.

In order to save space, detailed results are given in Table I of samples A to E and P only. In Figure 1 the points representing actual values found are not shown as in all cases they lie on or an inappreciable distance from their respective curves.

TABLE I.

As "moisture" is given the loss in weight on heating at 110° C. while "organic matter" represents the loss on ignition after removal of the moisture.

Sample A.

Jungle soil from Sungei Buloh Forest Reserve.

Weight of soil taken	=	335 grams.
Moisture	=	11.7 per cent.
Organic matter	=	6.0 per cent.

t = days from beginning of experiment.
y = total mgm. carbon dioxide per 100 g. soil.

t	y	t	y
2	10.8	24	91.6
4	25.0	29	104.3
7	39.3	36	118.0
9	49.1	42	130.0
11	57.5	49	139.9
19	77.5		

Sample P.

Peaty soil, which had received lime 3 years previously, from a rubber estate in Selangor.

Weight of soil taken, = 212 grams.
Moisture, = 35.0 per cent.
Organic matter, = 50.7 per cent.

t	y	t	y
2	7.9	56*	230.5
4	21.0	58	235.7
7	38.1	60	241.0
9	52.2	65	251.6
11	66.2	71	265.2
14	80.1	77	279.6
16	93.0	88	298.2
18	106.1	97	314.0
21	122.7	112	338.3
23	135.5	127	361.7
25	146.4	146	388.7
29	156.6	170	424.5
31	163.0	193†	464.5
33	168.0	195	466.6
35	174.7	199	470.2
39	182.2	202	475.3
43	200.6	207	481.7
51	218.5		

*After the 56th day, the soil was well shaken by hand and an inlet tube fitted under the surface so that in further experiments air was drawn through and not over the surface of the soil.

†After the 193rd day, the soil was washed with distilled water, roughly air-dried and then replaced.

The equation $y = F\ t^{m}$

Lemmermann and Weissmann found that carbon dioxide evolution from soil subjected to experimental conditions such as those described here was accurately expressed by the equation :—

$$x = a\ k\ t^{m}$$

where x is the amount of carbon dioxide formed in time t, a is the initial carbon content of the soil and k and m are constants.

Although these authors state that gas evolution from their soil samples followed this equation throughout, an examination of the data for their control reveals the usual initial period of adjustment, during which this expression does not apply.

The equation of Lemmermann and Weissmann accurately expresses the results of the present investigation, once equilibrium has been attained, but it is proposed to employ it in the form :—

$$y = F\ t^{\ m}$$

where y represents the amount of carbon dioxide produced in time t, and F and m are constants which are capable of useful interpretation.

The constants admit of ready evaluation by means of the equations,

$$m = \frac{\log y_2 - \log y_1}{\log t_2 - \log t_1}$$

where y_1 and y_2 represent the amounts of carbon dioxide evolved in times t_1 and t_2, and

$$\log F = \log y - m \log t.$$

Thus the plot of the logarithm of the carbon dioxide yield against the logarithm of the time is a straight line and from Figure 3 it will be seen that this is the case with the soil samples A to E and P, when the initial period of adjustment has been passed.

It will be seen also from Figure 3 that after the initial period has been passed, the curves for samples B and C are parallel; in other words these lines make the same angle $\tan^{-1} m$ with the X axis. It will be remembered that these samples are identical in all respects save in the amount of added water. Another pair of parallel lines is found in Figure 3 for the samples D and E, which differ only in that they were inoculated with different organisms.

These results suggest that, for a given soil, m is independent of changes in the biological population and possibly, within reasonable limits, of the moisture content of the soil. Further work would be required, of course, for the establishment of such a conclusion but the similarity of the m values is in sufficient contrast to the differences in the F values. The factor m represents a retardation in the rate of evolution of carbon dioxide, due probably to the artificial conditions of the laboratory.

Variation in the microbial activity of the soil is reflected in the constant F.

When $m = 1$, a condition which, it is reasonable to suppose, obtains in the field,

$$y = F\ t,$$

which expression means that carbon dioxide production proceeds at a uniform rate.

F, therefore, can be regarded as the amount of carbon dioxide produced in unit time under natural conditions and may be termed the "fertility constant" of the soil. Table 2 presents the values

which show that, while identical soils differently treated, may have the same values for m, the values for F may differ appreciably.

TABLE 2.

VALUES OF THE CONSTANTS m AND F

Soil Sample.		m	F
A	...	0.63	12.9
B	...	0.87	4.8
C	...	0.84	4.0
D	...	0.54	13.7
E	...	0.52	8.4
P	...	0.55	22.1

From the data and granting the assumption made, it is possible to construct curves representing the behaviour of the soil samples under natural conditions.. Were no retarding forces in operation, an amount y_1, of carbon dioxide would be produced, not in time t_1, but in time t_1, ^{m}; thus the required curves are obtained by plotting the values for y against those calculated for t^m or, more simply, the curves may be constructed by drawing straight lines passing through the origin, and making an angle $\tan^{-1} F$, with the X axis. This procedure can only be adopted, of course, for that part of the curve which follows the equation $y = F t^m$.

Figure 4 shows the curves obtained by this means for the samples A to E and P.

It is of some importance to obain exact information regarding the significance of the constants F and m in the equation and an attempt has been made to pursue the subject further by investigating the evolution of carbon dioxide from an eqeous solution of glucose in the presence of a pure cutlure of one organism.

Growth curves of various species of micro-organisms have been determined by a number of investigators (10). Usually the method adopted has entailed measurements of the changes in the cell population at time intervals when a pure strain is cultivated in a nutrient medium. All the growth curves so obtained conform to the same general type, an initial period of inactivity being followed by a rapid increase in the bacterial population, which, in its turn, is superseded by a decline in numbers.

In the present investigation the yield of carbon dioxide was measured in place of bacterial numbers, and the organism employed, a species of *Actinomyces*, was particularly suitable in that, under the experimental conditions, it degraded glucose completely to carbon dioxide. *Actinomyces* was easily maintained in pure culture and,

although its activities with regard to the soil were not investigated in any detail, it was found that it produced carbon dioxide from sterile soil, and whilst able to effect the decomposition of dead leaves in a humid atmosphere it was killed by exposure to direct sunlight.

The Decomposition of Glucose by Actinomyces.

After inoculation of a solution of known glucose content with *Actinomyces*, the carbon dioxide evolved was measured daily until the whole of the glucose had disappeared. The results are given in Table 3 and expressed graphically in Figures 5 and 6. Figure 5 represents the total yield of gas at any given time, whilst Figure 6 shows the carbon dioxide yield for 10 day periods.

Carbon dioxide evolution began immediately after inoculation, and the daily yield increased for the first 50 days. For the following 10 days, the daily yield remained somewhat steady but after this a decline set in. Thus a sigmoid curve is obtained by plotting the total yield of gas against the time (Figure 5) and is of the type usually found in such investigations.

Bacterial growth curves can be divided into a number of phases. Different workers do not agree on the details and nomenclature of such phases and the scheme advanced by Winslow (11), which has the merit of simplicity, has been adopted here. Winslow recognises 5 phases in the life cycle of a bacterial population under normal conditions, viz * (i) phase of adjustment, (ii) phase of increase, (iii) phase of crisis, (iv) phase of decrease and (v) phase of readjustment. It is difficult accurately to define these phases for, usually, one phase merges into the next without any sharp line of demarcation.

When bacteria are introduced into a medium favourable for growth and reproduction, their initial activities are not very marked. One reason for this is that their numbers are small and some time must elapse before a marked increase in the population can occur, and further, some time is required for the organisms to adapt themselves to altered conditions. In the present case, *Actinomyces* had been growing on glucose agar previously so the only change was from a solid to a liquid medium, and, as was anticipated, normal growth and reproduction occurred almost from the outset, the phase of adjustment (a-b in Figures 5 and 6) being of very short duration. The phase of increase (b-c in Figures 5 and 6) is characterised by a period of rapid and regular

* Not to be confused with the period of adjustment mentioned previously.

increase in cell reproduction and hence of carbon dioxide evolution. By means of Müller's formula (12),

$$G = \frac{t \log 2}{\log b - \log a}$$

where a and b are the initial and final bacterial numbers (but in this case the carbon dioxide yields), t the elapsed time and G the minutes per generation, it was found that during the first 15 days the generation time was nearly constant and equal to 1 hour. During the phase of crisis (c-d in Figures 5 and 6) the increase in numbers of bacteria falls off, and for a short period the carbon dioxide output remains nearly constant, before a marked diminution in the active population occurs. The duration of the phase of crisis varies with the organism and the medium employed but is usually comparatively short. It will be observed that the appearance of this phase was not due to any lack of nutrient.

The phase of decrease (d-e in Figures 5 and 6) comprises a comparatively large portion of the curve and throughout its duration there is a steady decline in the active bacterial population and hence in the rate of carbon dioxide evolution. The phase of decrease is of considerable interest in connection with carbon dioxide evolution from soils under laboratory conditions for it is this portion of the growth curve which corresponds to the soil curves depicted in Figures 1 and 2. As the decomposition of glucose by *Actinomyces* approaches completion a decline in the death-rate of the organisms sets in and the phase of decrease merges into the phase of re-adjustment, (e-f in Figures 5 and 6). In this latter phase conditions tend towards a state of stability and the disappearance of the small amount of nutrient remaining is very slow.

Experimental.

The medium used was that employed by Millard and Burr (13) for the growth of *Actinomyces* and comprised the following quantities of hydrated salts in 500 c.c. of water: di-potassium hydrogen phosphate, 0.5g.; magnesium sulphate, 0.25g.; potassium chloride, 0.25g.; ferrous sulphate, 0.005g.; sodium nitrate, 1.0g.; glucose, 15g. The *pH* was adjusted to 6.8.

The medium was sterilised in a litre flask and the apparatus was set up to permit a current of air to pass through the series: sulphuric acid bubblers, soda-lime tubes, a flask containing 15 per cent. sulphuric acid solution, the fermentation flask, and finally three small flasks containing standard sodium hydroxide solution. Before inoculation, apparatus was sterilised where necessary. After inoculation, the carbon dioxide liberated in the fermentation flask

was displaced by a current of air and collected in the flasks containing standard alkali solution.

Carbon dioxide was estimated by titration with hydrochloric acid after addition of barium chloride and in presence of phenol phthalein.

For the first 95 days readings were taken daily except on the 53rd and 55th days but, after this period, no readings were taken on Sundays.

The pressure of the gas in the fermentation vessel varied considerably and although, in this experiment, no barometric readings were made, it was observed that while the gas pressure in the fermentation flask exceeded that of the atmosphere initially, it decreased until a strong tendency to suck back was evident.

The experiment was stopped on the 253rd day and no glucose was found in the medium.

Throughout the experiment 20.0g. of carbon dioxide were collected whereas the theoretical yield was 22.0g. The weight of mycelium present in the fermentation flask was 0.73g. after drying at 110°C.; hence the yield of carbon dioxide from glucose was almost the theoretical value.

TABLE 3.

500 c.c. of Millard and Burr's synthetic glucose solution was prepared and inoculated with *Actimyces*. The carbon dioxide yield was estimated daily. At the beginning of the experiment, the solution contained 15g. glucose.

t = time in days.
y = yield of carbon dioxide in grams.

t	y	t	y	t	y
10	0.070	100	13.492	190	19.638
20	0.187	110	14.573	200	19.721
30	0.444	120	15.845	210	19.811
40	1.629	130	17.005	220	19.880
50	4.199	140	17.974	230	19.935
60	6.791	150	18.598	240	19.983
70	8.971	160	19.004	253	20.004
80	10.651	170	19.311		
90	12.067	180	19.478		

The interpretation of the constants F and m in the equation $y=F\ t^{m}$.

The Constant *F*.

We are now in a position to consider more fully the significance of the constants *m* and *F* in the equation $y=F\ t^{m}$. It is evident that the only portion of the *Actinomyces* growth curve which is relevant to the question is the phase of decrease which extends from the 60th to the 130th day.

In this connection it has to be considered whether, in the equation $y=F\ t^{m}$, *y* is to be regarded as the total yield of carbon dioxide in milligrams from the beginning of the experiment or the total yield from the 60th day. If *y* be taken as the gas yield from the beginning of the experiment the equation is followed only between the 80th and 130th days and the values obtained for *m* and *F* are 0.95 and 167.9 respectively.

On the other hand, if the 60th day be taken as the zero time, it is found that the equation is satisfied throughout the whole of the phase of decrease, i.e. from the 60th to the 130th day. The constants *m* and *F* then have the values 0.79 and 277.3 respectively.

The value 167.9 for the constant *F* has no precise meaning, but the second figure obtained, 277.3, has a very definite significance. It is the daily yield of carbon dioxide in milligrams at the 60th day.

It is reasonable to compare the soil curves with that portion of the *Actinomyces* curve covered by the phase of decrease and to regard the latter as a separate entity by taking the 60th day as zero; for the soil curves give no indication of the presence of true phases of increase and crisis. It is true that, usually the maximum yield of carbon dioxide is not attained on the first day but this is almost certainly due to the fact that some little time is required for the soil micro-organisms to adapt themselves completely to experimental conditions.

There can be little doubt that it is this difficulty of adaptation which results in the initial period of adjustment characteristic of all the soil curves, and during which the equation $y=F\ t^{m}$ is not accurately followed. Nevertheless, in view of the presence of this period of adjustment, it is remarkable that, after the lapse of 2 or 3 weeks, the equation is accurately followed. Incidentally, it has been found that the adjustment period can be curtailed by grinding and sieving a soil before use, so that only small particles of uniform size are employed. In the *Actinomyces* experiment, the organisms had already become adapted to prevailing conditions when the phase of decrease was reached, so in this case the equation was followed accurately throughout the whole of that phase.

There appears to be every justification for regarding the values of F obtained for the soils considered previously as representing the daily yield of carbon dioxide at the beginning of the experiment, before experimental conditions had produced an inhibiting effect. The daily carbon dioxide yield at the beginning of the experiment must be very close to the daily output of the same soil in the field. According to Jenny (14), when usual conditions obtain, at temperatures near 25°C. the humus content of the soil is constant, humus formation and decomposition proceeding at the same rate. An accumulation of humus occurs in soil at temperatures below 25°C. while, above this temperature, the decay of organic matter outpaces its formation. Haines (15) has shown that the mean temperature of the air and soil in Malayan jungle is 75-76°F. (= 23.9-24.4°C.), the daily variation in soil temperature, even at the surface, being only 1°F. Thus there is reason for believing that local soils under jungle give an almost constant daily yield of carbon dioxide and, judging by the results of plate counts of the soil micro-organic population, conditions under mature rubber cannot be very different. It appears unlikely then that any appreciable error is introduced by regarding the F values as representing the daily yield of carbon dioxide in the field.

It has been pointed out previously that temperature changes were not taken into account in this investigation. In Malaya, laboratory temperatures have a daily range between 26° and 29°C., but no seasonal variation; in temperate countries work of this nature will necessitate the use of some constant temperature device if results comparable amongst themselves are to be obtained.

The Constant m.

Representing as it does, the retardation in the rate of carbon dioxide evolution during the phase of decrease, m may have any positive value not greater than unity. When m is equal to unity, gas evolution takes place at a constant velocity.

The reason for the decline in bacterial numbers and in carbon dioxide evolution here described has been the subject of several investigations, but little progress has been made towards a solution of the problem. There is no doubt that the decline in the rate of carbon dioxide evolution which occurred in the soil experiments is attributable to the same cause as resulted in the appearance of a phase of decrease in the *Actinomyces* experiment. This phenomenon has no very obvious connection with the food supply and appears invariably in all investigations concerned with the growth of micro-organisms. In the case of the soil micro-

organisms it does not appear to be connected with the formation of toxic bodies or inefficient aeration but it is well known that when soils are washed with fat solvents such as toluene and chloroform a marked increase in the bacterial population occurs. It was thought that this point might bear some relation to the problem.

Certain species of soil micro-organisms possess the ability to synthesise fatty substances and soils exposed to direct sunlight are known to have a higher fat content than soils under shade. It is possible, however, that the higher fat content of soils in dry situations may be due rather to the absence of fat-splitting organisms than to the presence of fat-synthesising species.

Air-dried soil from Sungei Buloh Experiment Station was extracted with chloroform and found to contain 0.16 per cent. of chloroform-soluble material. After addition of water and a small quantity of fresh, untreated soil, the decomposition of the organic matter in the fat-free soil was followed by measurement of the carbon dioxide evolved in the usual manner. The results obtained from the chloroform extracted soil and from a control are expressed in Table 4 and Figure 7.

TABLE 4.

Sample G.

Soil from Block 15, Sungei Buloh Experiment Station. Air-dried soil was extracted with chloroform in a Soxhlet apparatus. 181g. of this soil were taken and 20 c.c. of water added. The sample was inoculated with about 1g. of fresh soil from the same origin.

t = days from beginning of experiment.

y = total mg. carbon dioxide per 100g. of soil.

t	y	t	y
3	20.9	42	111.5
7	41.0	45	120.5
10	51.6	49	129.4
14	61.6	52	134.7
17	68.9	56	142.2
22	78.0	60	149.0
25	83.7	63	155.6
28	89.5	67	163.3
31	94.7	71	171.4
35	100.2	74	177.1
39	105.7		

Sample H.

Particulars identical with those of the previous sample except that the chloroform treatment was omitted.

t	*y*	*t*	*y*
2	16.9	26	93.4
5	34.5	29	101.3
9	52.0	32	108.3
12	63.6	36	115.9
16	73.8	39	123.5
19	79.5	44	131.6
24	89.9	46	136.4

It will be seen from the figure that after the 42nd day a rather sudden change occurred in the gas yield from the fat-free soil and from then onwards a new curve was traced. Both portions of the curve followed the usual equation and so two sets of values for the factors m and F were obtained (see Table 5). The control sample which differed from the first soil only in that it had not been treated with chloroform, gave a curve of the usual type. It is interesting to note that although the curve for the control lies above that for the fat-free soil in Figure 7, it has a lower F value initially, the chloroform treatment having raised the fertility constant from 11.3 to 14.3 milligrams of carbon dioxide per day.

TABLE 5.

Values for the constants m and F.

Sample		m	F
G. (to 42nd day)	...	0.55	14.3
G. (42nd to 74th day)	...	0.94	2.5
H.	...	0.65	11.3

The somewhat abrupt change in the course of gas evolution in the fat-free soil after the 42nd day may represent a change over from the phase of decrease to that of re-adjustment. Certain nutrient materials have doubtless been removed by the chloroform treatment and the break in the curve may, perhaps, signalise the completion of the removal of certain other readily available sources of energy. The fact that a few other soils of low organic matter content have been found to depart from the normal curve after 5 or 6 weeks lends support to this explanation.

In reviewing the results obtained in all the experiments as far as the m values are concerned, it cannot be claimed that our knowledge of this constant is very complete. The numerical value of m is unchanged by alteration of the moisture content and is independent of the species of micro-organisms present; but it is affected by the addition of certain chemicals to the soil and by drastic treatment such as chloroform extraction. At present, m can be regarded as a measure of the falling off in the rate of bacterial growth which is inseparable from experiments entailing the employment of cultures of micro-organisms; its precise significance is not of great moment as far as the practical utility of the equation $y=F\ t^{\ m}$ is concerned. A knowledge of the numerical value of m is essential for the determination of F, the fertility constant, and it is this latter factor which is of practical importance.

The Bacteriological Aspect of the Manuring of Rubber.

The problem of increasing latex production by the application of fertilisers to the soil differs in several respects from that of increasing the yield of fruit or roots in an annual crop in a temperate climate. Compared with an annual crop the rubber tree is slow growing and immediate results from manuring are hardly to be expected. Moreover, the factors which govern latex flow are still but imperfectly understood, although Ashplant and, later, Frey-Wyssling (16) have demonstrated that some relationship exists between the diameter of the latex tubes and the yield of dry rubber. The latter author has shown that trees with narrow tubes are poor yielders, but the converse is not necessarily true; for there are reasons why trees with wide latex tubes may be poor yielders.

There appears to be no reason for supposing that latex yield may be increased over a lengthy period by application of chemical stimulants. On the other hand, it is known that by judicious manuring soil conditions may be improved and, in consequence of improved health, the rubber trees will give satisfactory yields over long periods. It is obvious that healthy trees must be more economic latex producers than those which are ill-nourished or suffering from disease. Thus the first essential in manuring rubber is the improvement of soil conditions.

Addition of a fertiliser to the soil may alter its physico-chemical properties or it may effect a change in the bacterial population. Usually, both results are to be expected.

Many fertilisers are very definitely dependent on the activity of the soil micro-organisms for their success, whilst others con-

tain plant nutrients in a form readily available for assimilation by the growing plant.

Sulphate of ammonia enjoys a widespread popularity as an artificial manure. It is possible that a certain amount of nitrogen may be taken up in the form of ammonia by some plants but, whilst we have no convincing proof of this, it is well-known that most plants derive their nitrogen supply from nitrates present in the soil solution. Ammonium salts are oxidised to nitrates by the agency of soil micro-organisms; and when soil conditions are unsuitable for the growth and reproduction of the appropriate species of bacteria, it is evident that nitrate formation will proceed but slowly and most of the added ammonia will disappear in the drainage water. If application of ammonium salts as fertilisers is to be attended with success, an increase in the microbial activity of the soil should be evident within a short space of time.

On the other hand, nitrogen is present in a form immediately available for plant food in sodium nitrate. It is certain, however, that mineral salts profoundly influence the activities of the soil micro-organisms by effecting changes in the concentration of the soil solution and in its reaction. In general, it would be anticipated that if such changes do not result in an increased activity of the micro-organisms present in the soil, deleterious rather than favourable effects will accrue.

Addition of lime to the soil may be cited as a case where both physico-chemical and bacteriological properties of the medium are changed. The *pH* of the soil will be increased and by such means the growth of a different set of micro-organisms will be encouraged. In fact, if argument is permissible from an analogy holding in temperate regions, the tendency will be for bacteria to thrive at the expense of the fungi.

It seems evident that the value of an artificial manure for ameliorating soil conditions is so frequently related to its ability to increase microbial activity that this is a safe premise to work on when dealing with soils under rubber, for little definite information is available concerning the manurial requirements of *Hevea*.

Some experiments have been carried out by the writer in this connection and the subject has been approached from two points. In the first place, the effects upon the soil bacterial population of addition of fertilisers were followed in the field by the plate count method. This method did not yield satisfactory results and was abandoned after a preliminary trial. Next, laboratory experiments were carried out in which the rate of carbon dioxide evolution of the soil was measured after addition of various artificial fertilisers. This method gave definite results and permits of practical application.

Experimental.

(a) *Field Experiments.*

A site was selected at the Institute's Experiment Station on which the soil was fairly uniform in texture and comprised the usual sandy layer overlying a clay sub-soil. The experimental block was divided by deep drains into a number of small plots, each 16 feet by 22 feet. Details of the treatments are given below:—

Plot.	*Fertiliser.*	*Cwt. per acre applied.*
1 A ...	Lime ...	3
1 B ...	„ ...	2
1 C ...	„ ...	1
2 A ...	Sulphate of potash ...	3
2 B ...	„ „ ...	2
2 C ...	„ „ ...	1
4 A ...	Sulphate of ammonia ...	3
4 B ...	„ „ ...	2
4 C ...	„ „ ...	1
5 A ...	* N.-P.-K. ...	3
5 B ...	N.-P.-K. ...	2
5 C ...	N.-P.-K. ...	1
5 Controls	— ...	—

* A mixture containing nitrate, phosphate and potassium.

Bacterial counts were made of the soil on each plot at weekly intervals before and after the application of fertilisers. None of the soil samples gave results which were consistently and appreciably higher than the control samples. From this it was concluded that the fertilisers used, in quantities of not more than 3 cwt. per acre, had no marked effects on the activities of the soil micro-organisms. Moreover, it was evident that the present method compared unfavourably with the carbon dioxide measurement method when it became necessary to detect relatively small changes in biological activity.

(b) *Laboratory Experiments.*

A large soil sample was taken from one of the control experimental plots and, after air-drying and passage through a 0.5 m.m. sieve, 250g. were weighed into each of 5 flasks. To each flask were added water, to the extent of 12.5 per cent., a small amount of fresh soil from the same plot, and 0.029g. of fertiliser. This weight of fertiliser was taken as equivalent to 5 cwt. per acre

but in the conversion formula, two arbitrary factors occur. It seems usual in calculations of this nature to consider the weight of the top 9 inches of soil as the effective depth. This procedure has been followed here, but it was found experimentally that very few micro-organisms occurred below 6 inches in this soil under field conditions. The specific gravity of the soil was taken as 2.7, but this, again, is rather a generous estimate and would require drastic reduction for soils of a more peaty nature. The carbon dioxide production was then measured in the usual manner; the results are plotted in Figure 8.

As a matter of interest, a similar experiment was carried out in which excessive quantities of fertilisers were employed. To 250g. of soil, 12.5 per cent. water and 18.4g. of fertiliser were added. The results are shown in Figure 9; it will be observed that bacterial activity was inappreciable in the soil with added lime.

The effects of fertilisers on the biological activity of the soil.

In Figure 9 the curves show considerable divergence in the rate of carbon dioxide production, whilst in Figure 8 the differences are not marked. From the preceding parts it will be realised that the difference in the rates of gas production depicted in the figures may be connected with differing biological activities of the several samples or may only indicate changes in the values of m.

In all cases the equation $y=F\ t^{m}$ is accurately followed after variable but usually short initial periods of adjustment, and the values found for the constants m and F are given in Table 6.

TABLE 6.

	5 cwts. per acre.		150 tons per acre.	
Fertiliser.	m	F	m	F
Control ...	0.60	14.5	0.72	10.3
Lime ...	0.60	14.5	—	—
Sulphate of potash ...	0.60	14.5	0.54	14.6
Sulphate of ammonia ...	0.59	14.8	0.65	4.5
N-P-K. ...	0.53	20.0	0.87	7.1

The field experiments show that the application of fertilisers at the rate of 3 cwts. per acre had no marked effect on the biological activity of the particular soil. The laboratory experiments make it clear that 5 cwts. of fertiliser per acre was also without effect save in the case of the N—P—K mixture. This substance raised the F

value of the soil sample from 14.5 to 20.0 which means an increased daily yield of carbon dioxide and hence an increase in biological activity of nearly 40 per cent. It is probable that the nitrate or phosphate (or both) must be held responsible for this rise as sulphate of potash alone had no effect. From these results it is fair to conclude that application of lime, sulphate of potash or sulphate of ammonia at the rate of 5 cwts. per acre is hardly likely to give economic returns on this particular soil.

Although of no immediate practical importance, the experiments in which large quantities of fertiliser were used are of interest in showing the toxic effect of addition of large quantities of chemicals to the soil. After addition of lime to the soil inappreciable amounts of carbon dioxide were evolved, whilst sulphate of ammonia and the N—P—K. mixture had also a depressing effect; sulphate of potash raised the F value by an appreciable amount.

In connection with the toxic effect of large quantities of lime, a paper by Hutchinson and MacLennan (17) is of interest. These authors found that different soils required widely differing amounts of lime to effect specific changes in the soil flora and fauna and each soil examined appeared to absorb a definite amount of calcium oxide; when these requirements were fulfilled further addition of lime resulted in a sudden decrease and subsequent increase in the numbers of bacteria present. The subsequent rise in the bacterial population is doubtless attributable to a gradual reduction of the lime present by natural causes until the amount fell below the toxic value.

The soil used for the present investigation was under primary jungle as recently as 2 years before the experiment was begun so it was probably not yet in need of any fertilisers. It was found, however, that when the method described here was applied to soils on an older rubber estate, much smaller quantities of fertiliser produced definite increases in biological activity.

The period of adjustment referred to above was much curtailed in soils containing added fertiliser. In most cases the equation $y = F\ t^m$ was followed after a few days so that a preliminary series of experiments need take little more than 3 weeks to give accurate values for F.

Summary.

The low bacterial population of Malayan soils renders the plate count method unsuitable as a means of comparing the biological activities, and hence the fertilities of different soils. Moreover, accurate values for the biological activity of soil cannot be expected of this method where only a proportion of the total organisms present are cultivated.

Such accurate values, however, can be obtained from a method described entailing estimation of the carbon dioxide yield of soils in the laboratory. This method depends on the fact that after an initial transitory period the equation

$$y = F\ t^{m}$$

is followed, where y is the yield of carbon dioxide in time t and F and m are constants. This formula has been investigated through observation of the fermentation of glucose by a single organism.

The constant F, termed the fertility constant, is concluded to be a measure of the daily yield of carbon dioxide by any given soil in the field. As yet the constant m has not been fully interpreted but it represents a retardation in the rate of gas evolution.

The manuring of rubber by chemical fertilisers is generally connected with the effects of such manures on the soil micro-organisms. By means of the carbon dioxide method the effect of different fertilisers on soil fertility can be assessed and hence the type and quantity of fertiliser required to increase biological activity on any given soil can be determined.

NOTE.

Two valuable suggestions, the results of which are embodied in the following note, have been made by Mr. W. N. C. Belgrave, B.A., Plant Physiologist, Department of Agriculture, S.S. and F.M.S.

The degree of aeration of certain heavy clay soils occurring in tropical plantations may be so slight that an error is introduced by examining them under the experimental conditions above described. If aeration be a limiting factor, the disturbance to which a soil sample is subjected in the laboratory may lead to an altered value of F.

In order to test this point the following experiment has been set up against a control as described before. The soil sample is removed from the ground by means of a wide metal bore which is placed in a cylindrical vessel and the evolution of carbon dioxide is observed over a long period. If identical values of F are obtained it will be established that even a low degree of aeration such as obtains in local heavy soils does not affect the issue.

In a further experiment the effect of rainfall is introduced by addition of water at the top and removal of drainage water at the bottom of the vessel. If this experiment gives a higher value for m than that given by a control it will indicate that the observed decrease in yield of carbon dioxide when soils are subjected to laboratory conditions may be due to the formation of toxic bodies, normally eliminated by drainage in the field.

These experiments are now in progress and thanks are due to Mr. Belgrave for his constructive criticism.

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(10) See, for instance, Buchanan, R. E. (1928). "Newer knowledge of bacteriology and immunology," (Univ. Chicago Press), p. 46 and Winslow, C-E. A., *ibid,* p. 58.

(11) Winslow, C-E. A. (1928). "Newer knowledge of bacteriology and immunology," (Univ. Chicago Press), p. 56.

(12) Müller, M. (1895). Zeitschrift für Hygiene und Infektionskrankheiten, **20,** 245.

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(14 Jenny, H. (1928). Journal of the American Society of Agronomy, **20,** 900.

(15) Haines, W. B. (1928). Rubber Research Institute Annual Report, p. 103.

(16) Ashplant, H. (1928). Nature, **121,** 1018. Frey-Wyssling, A. (1930). Archief voor de Rubbercultuur, **4,** 135.

(17) Hutchinson, H. B. and MacLennan, K. (1914). Journal of Agricultural Science, **6,** 302.

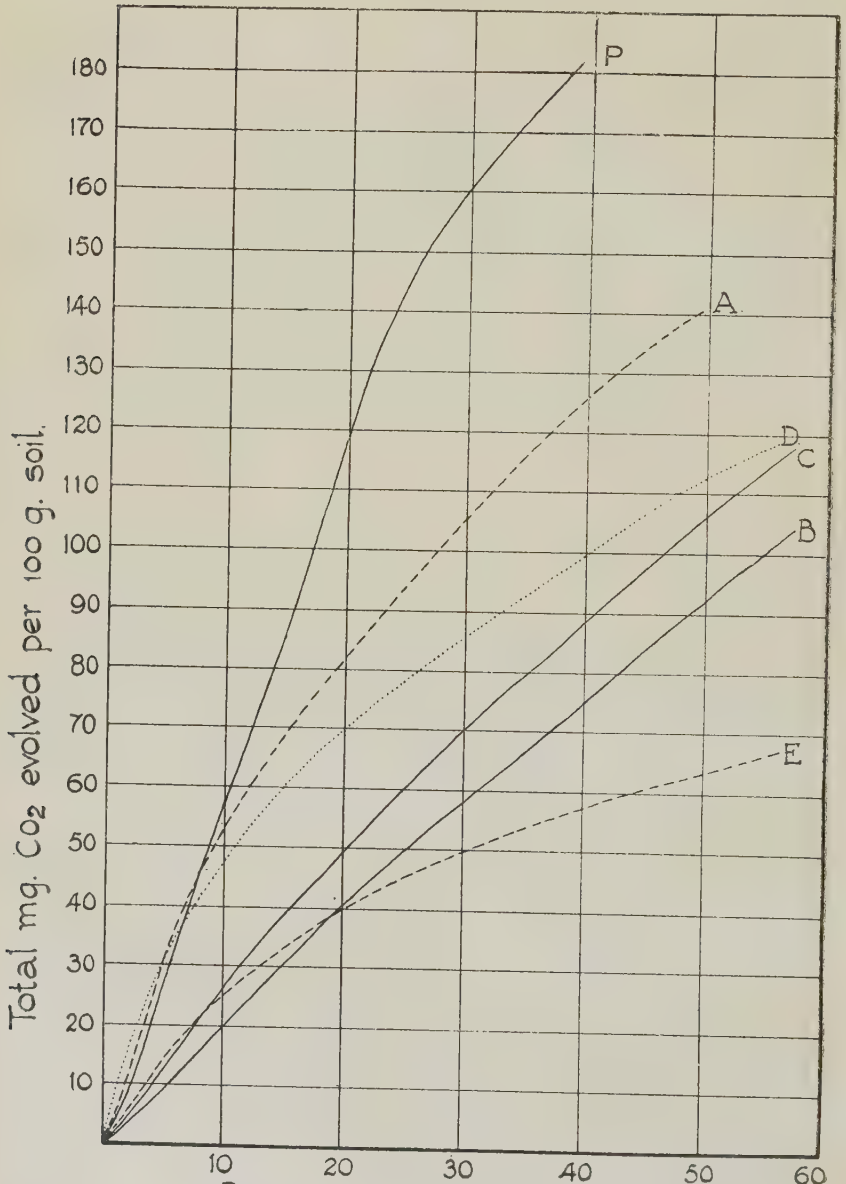

Total mg. CO_2 evolved per 100 g. soil.
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
10
20
30
40
50
60
Days.
P
A
D
C
B
E

FIGURE 1.

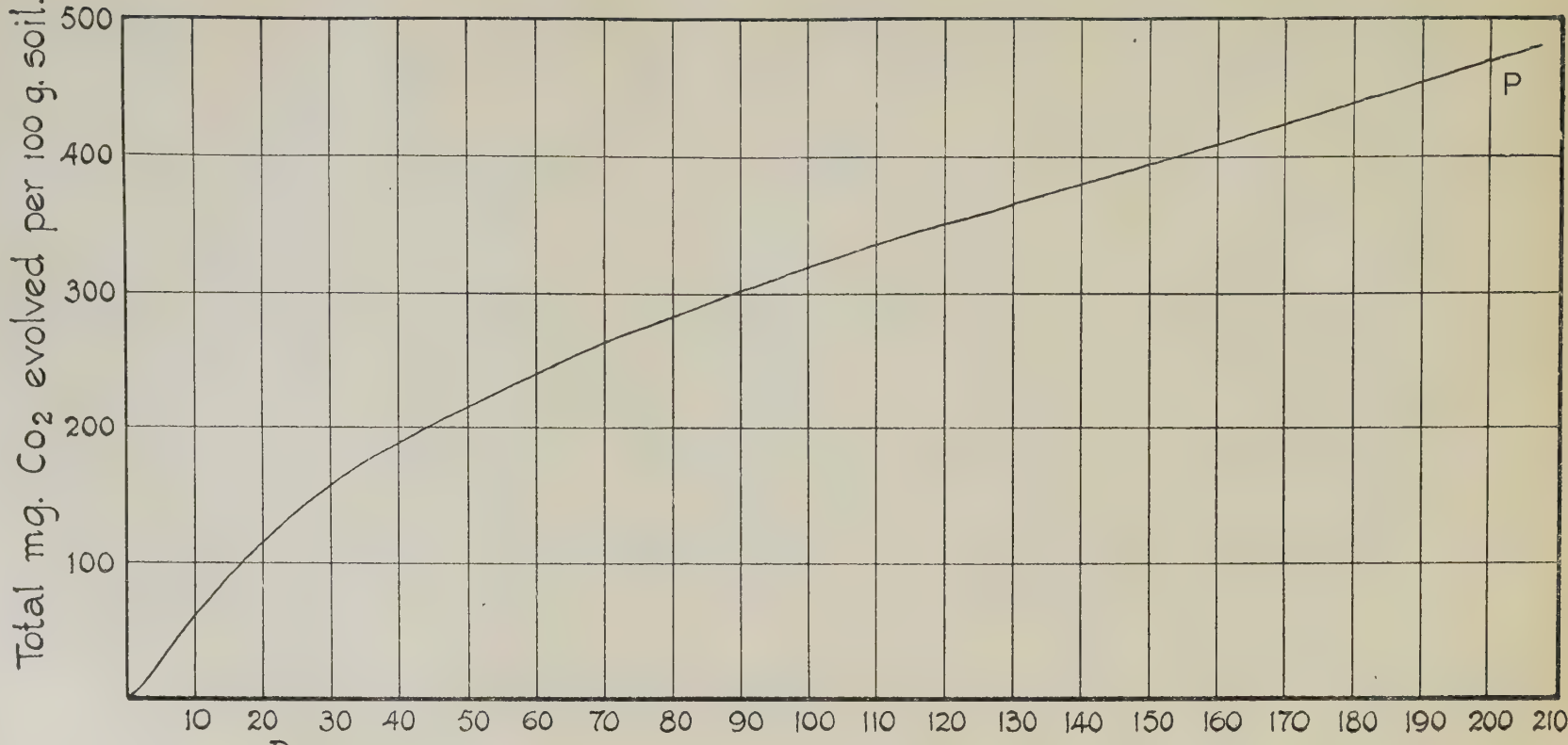

Total mg. CO_2 evolved per 100 g. soil.
500
400
300
200
100
P
10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210
Days.

FIGURE 2.

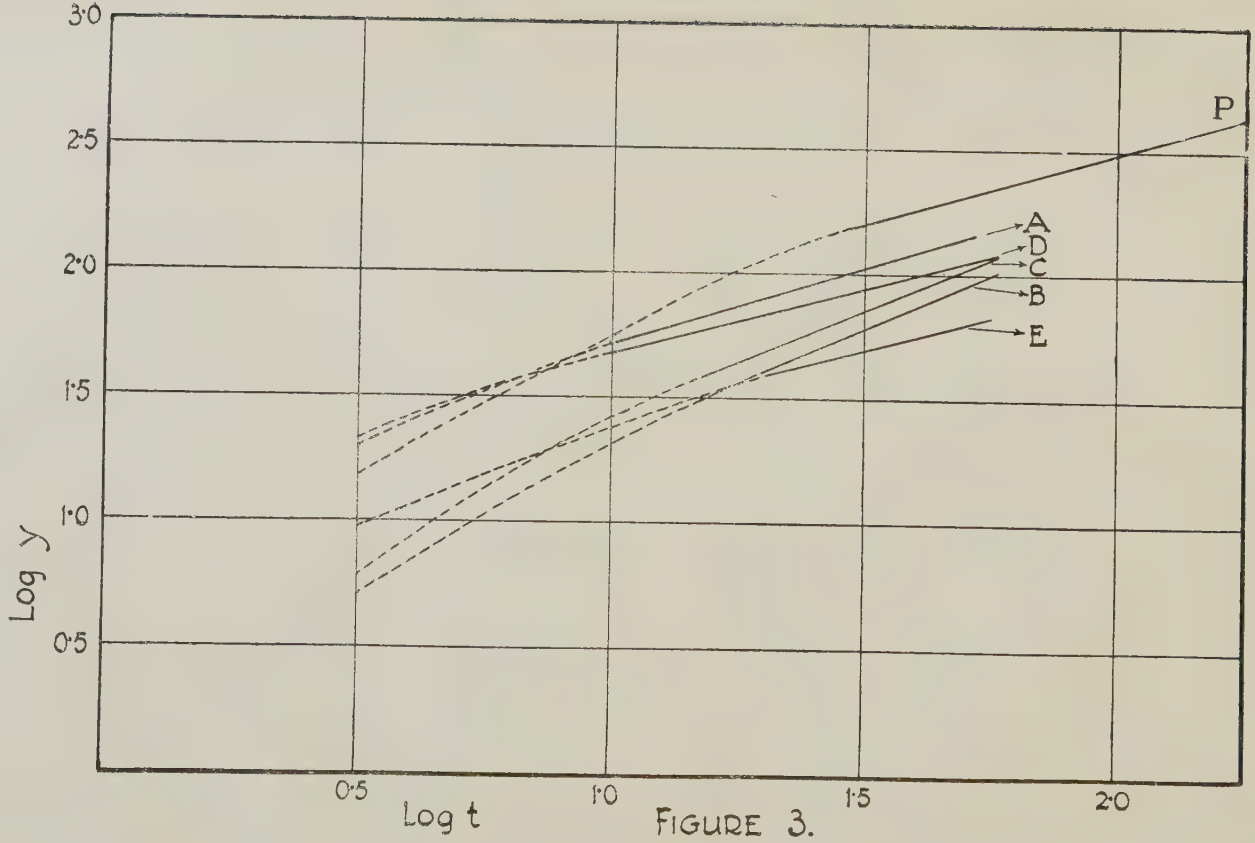


FIGURE 3.

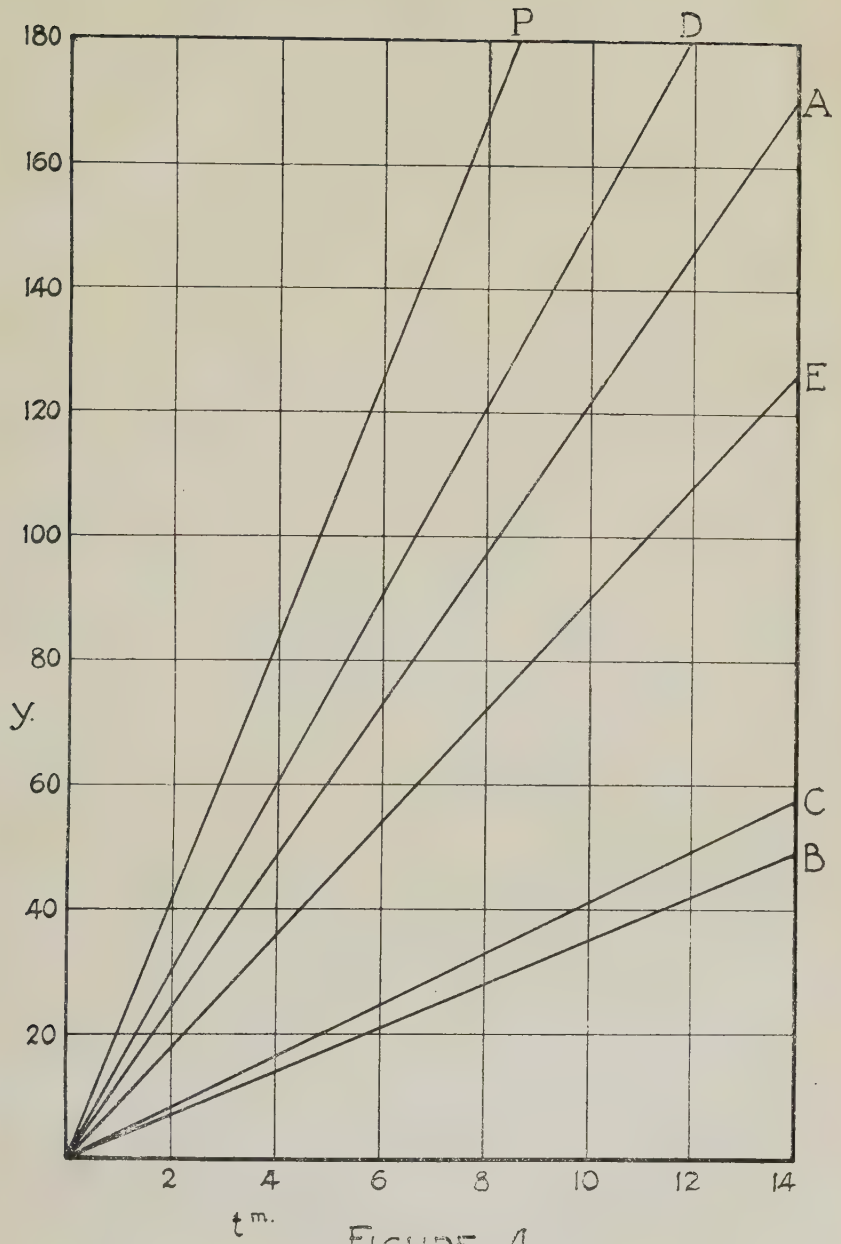


FIGURE 4.

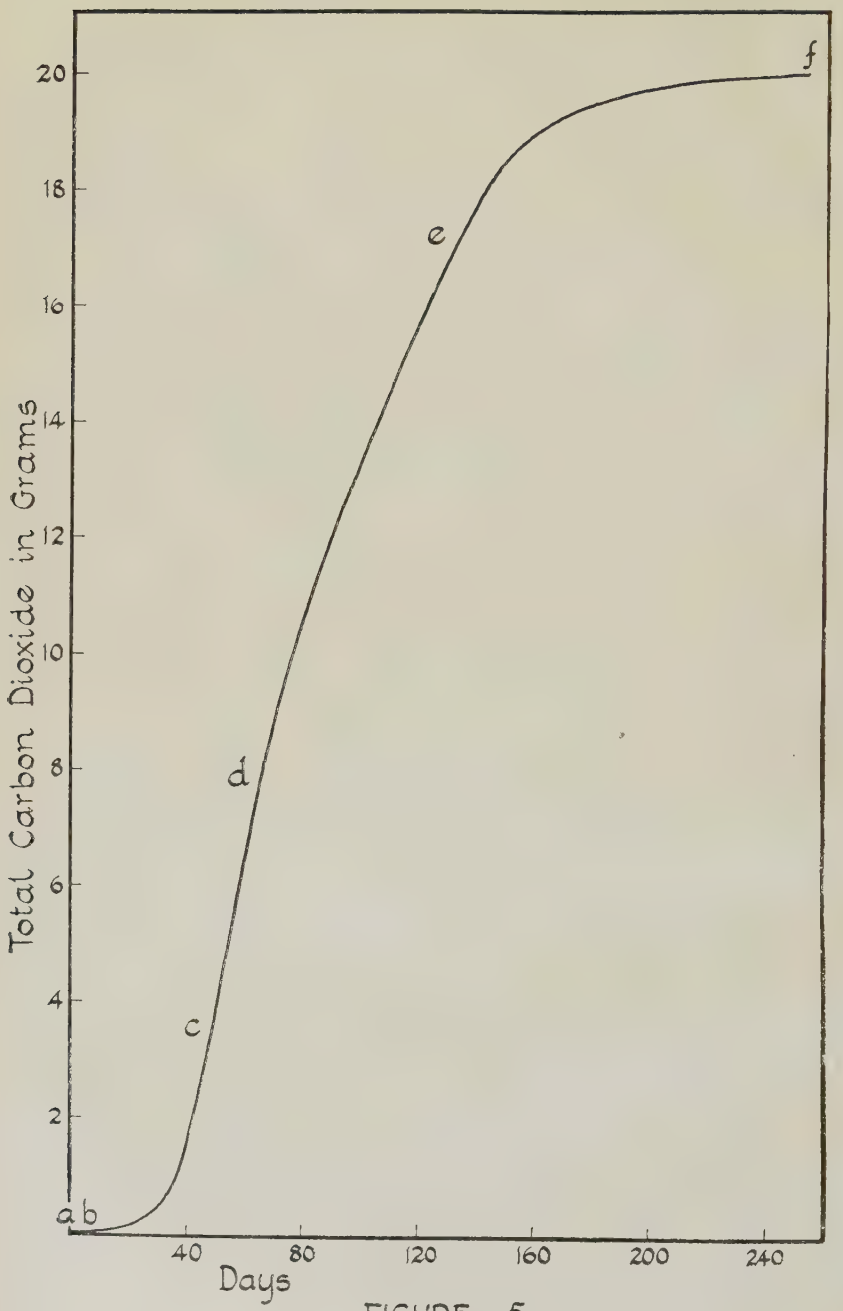

Total Carbon Dioxide in Grams
20
18
16
14
12
10
8
6
4
2
a b
c
d
e
f
40
80
120
160
200
240
Days

FIGURE 5.

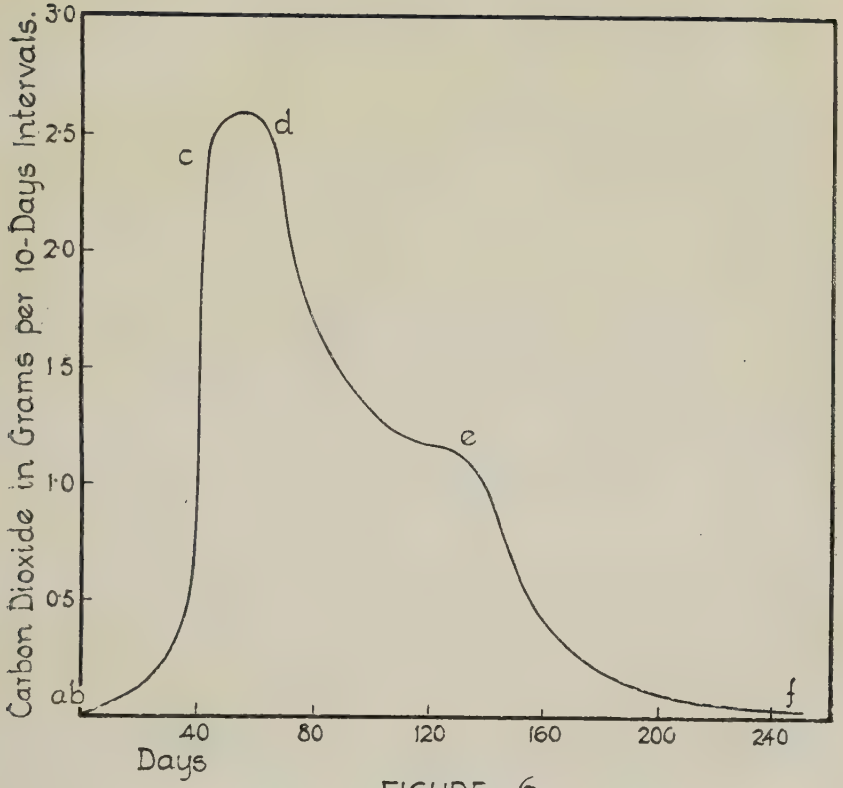

Carbon Dioxide in Grams per 10-Days Intervals.
3·0
2·5
2·0
1·5
1·0
0·5
a b
c
d
e
f
40
80
120
160
200
240
Days

FIGURE 6.

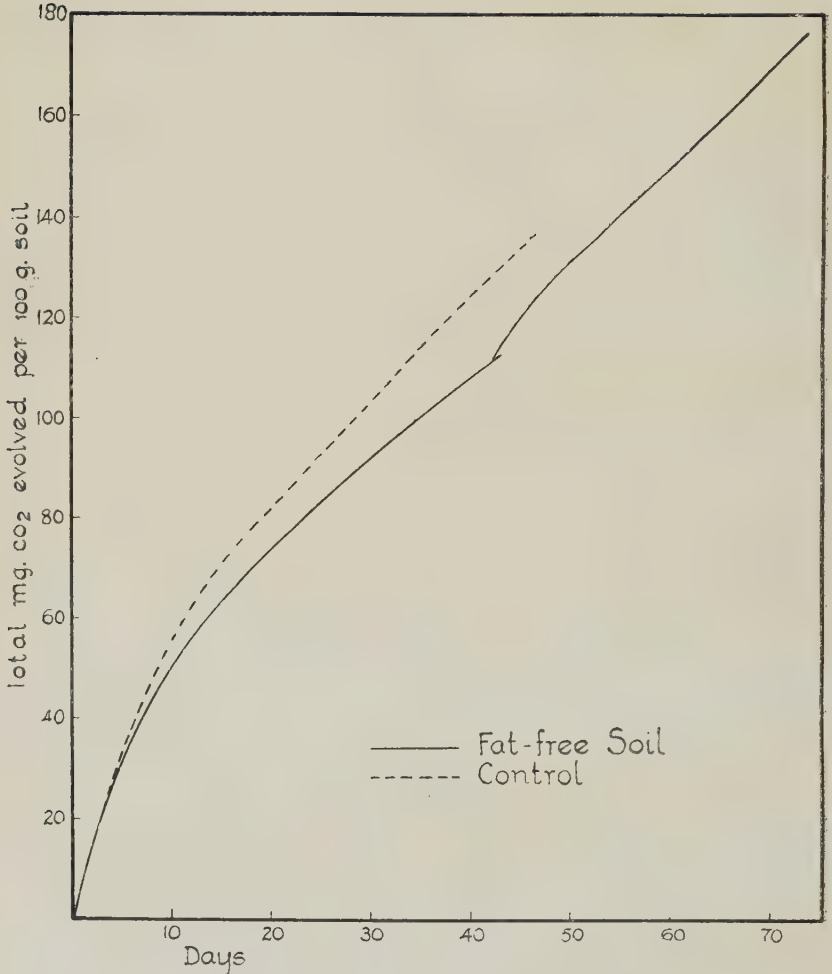

180
160
140
120
100
80
60
40
20
Total mg. CO_2 evolved per 100 g. soil
10
20
30
40
50
60
70
Days
Fat-free Soil
Control

FIGURE 7.

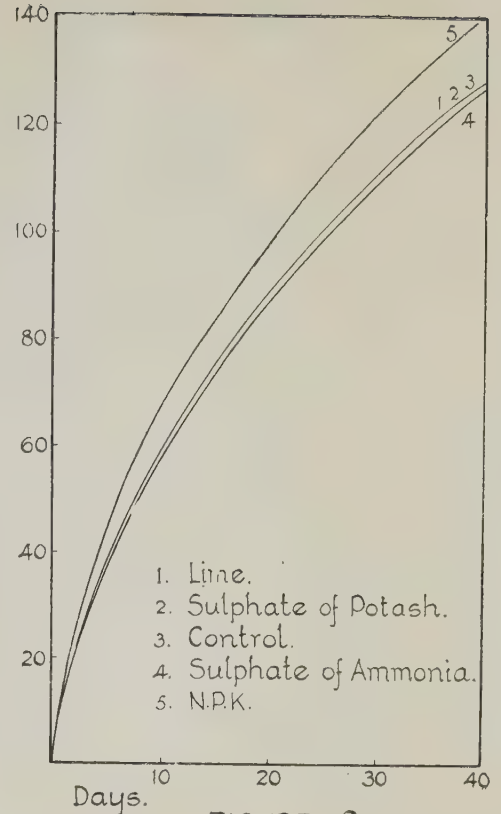


FIGURE 8.

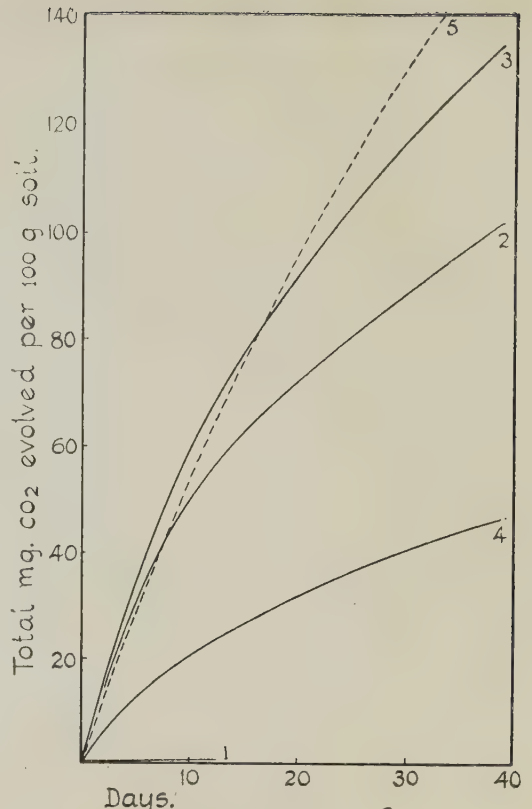


FIGURE 9.

EFFECT OF COVERS AND CLEARING METHODS ON THE GROWTH OF YOUNG RUBBER.

BY

A. R. Sanderson and W. B. Haines.*

The following article discusses height and girth measurements made on certain blocks of young rubber laid down at the Experiment Station of the Rubber Research Institute by the Pathological Division (originally designed by Dr. J. R. Weir). The age of the trees, at the time of measurement in May, 1930, was approximately 18 months. The varied experimental conditions include clean clearing (which term, in this paper, means the removal of all stumps and surface timber but leaving everything else below the surface), the leaving of all surface timber after burning, and reversion to belukar (secondary jungle) after burning. In addition, the plots allow of comparison between clean weeding and various cover plants. The results bear out various interesting observations and effects, but it cannot be too clearly emphasised at the outset that the conclusions only apply to rubber of a very young age, and that it would be misleading to attempt too much in the way of forecasting future behaviour. It is a general observation that growth evens up at later stages, so that any early differences need not necessarily be the ruling features in later developments, though they clearly indicate what is going on in the earliest stages.

The whole of the area concerned is practically flat with a uniform sandy soil throughout. In an experiment on a similar contiguous block the standard error of similar measurements was just under 4 per cent, which may be taken as some guide to the uniformity to be expected.

Blocks 7 and 8.

Blocks 7 and 8 are two squares of 10 acres each, lying side by side. The rubber trees were planted 22 feet by 22 feet in the middle of December, 1928. On Block 7 all stumps and logs were left lying after the burn while on Block 8 all stumps and surface timber were removed. Each block is divided from north to south into three strips, which were planted up with seed at

* The MS. has been revised in the absence of the senior author, who is therefore not necessarily to be held responsible for all the views expressed.

stake, basket plants and stumps respectively. From east to west each block is divided into six strips (five rows of trees in each strip) and of these, alternate strips were planted with *Calopogonium mucunoides, Crotalaria anagyroides* and *Leucaena glauca* respectively, the intervening strips being clean weeded. Previous to the measurements alternate trees on part of Block 8 had been budded. Although this somewhat limits the utility of the data there remain sufficient of the original trees to give fair averages. It may be remarked that the budding is unlikely to have seriously affected the remaining trees, as they were still small for questions of altered light and space to produce much effect, especially as the period between cutting back of the buddings and date of measurement was only four months.

A comparison of growth (average heights) is set out in Table I for the various plots and planting material. The accompanying diagram sets out the same data in graphical form. For the calculation of the averages the rows of trees along the edge of the strip boundaries (cover and clean weeded) were discarded, thus leaving three rows for inclusion. The figures with an asterisk are those for which only half the number of trees were available for the average, owing to the budding work.

From Table I we may deduce that basket plants have proved the best planting material. Stumps have proved very nearly as good up to this stage, but this comparison must be discounted by remembering the original advantages enjoyed by the stumps, which not only had a reserve of food material but also began growth with a start of some eighteen inches in height. They are definitely older trees. Seed at stake are very definitely behind the basket plants. The four comparisons provided between the two kinds of material, where other conditions are the same, give an average showing the basket plants 21.6 per cent. in advance of the seed at stake.

Growth on the clean weeded plots has been about the same for cleared as for uncleared ground. The effect of covers in retarding growth has been about twice as great on the cleared land as on Block 7 with the timber left lying. It is interesting to note that the effect of the covers was definitely smaller (scarcely significant) on the plots of best growth (basket plants with timber left lying.) This uniformly good growth of basket plants among the timber indicates that the retarding effects of cover are at a discount where other conditions are sufficiently favourable. The number of supplies required in Block 7 was 21, while Block 8 had 41 up to the same time. Thus losses were small but were definitely higher on the clean cleared land. The fuller significance of these results will best be discussed after the data for other Blocks have been presented.

TABLE I.

Mean heights in inches (30 trees to each group*).

		Cover.		Control (Clean Weeded.)		Percentage Advantage of Weeded over Cover.
Block 7 Timber Left.	Seed at Stake	124.0 95.7 128.2	116.0	141.7 117.2 136.6	131.8	13.3 per cent.
	Basket Plants	145.4 150.5 153.3	149.7	146.0 158.8 163.0	155.9	4.1 ,, ,,
	Stumps	118.3 126.0 147.6	130.6	162.0 139.4 168.6	148.1	13.5 ,, ,,
	Mean.		132.1		145.3	10.1 ,, ,,
Block 8. Clean cleared.	Seed at Stake	93.7 99.8 128.5*	107.7	121.7 128.9* 126.4*	125.7	16.9 ,, ,,
	Basket Plants	95.4 128.7 150.0*	124.7	153.9 168.1* 143.6*	155.2	24.8 ,, ,,
	Stumps	102.9 96.8 161.0*	120.2	155.0 132.7* 173.1*	153.6	27.6 ,, ,,
	Mean.		117.5		144.8	23.1 ,, ,,

* Averages so marked are for 15 trees only.

Block 9.

This Block consists of eight acres, of which half was left with surface timber and half clean cleared; planted seed at stake in January 1929, planting distance 22 feet x 22 feet, clean weeded in both areas.

Surface timber left	-	mean height	-	139.7 inches.
		mean girth at 3 ft.	-	3.93 „
Clean cleared	-	mean height	-	142.9 „
		mean girth	-	4.06 „

Here the differences are too small to be regarded as significant. It is to be noted that the growth is rather better than on the comparable areas of Blocks 7 and 8, but agrees as regards equality for cleared and uncleared when clean weeded.

Block 10.

Nine acres of Block 10 were planted with seed at stake at the end of February, 1929, all stumps and surface timber being removed. Vigna was planted during April along alternate strips containing two rows of trees and has made good growth from the start. The width of the strips is so narrow that a comparison of growth can scarcely be expected to bring out the full effect, but the figures indicate a retardation due to the cover. The growth on the whole plot is not so good as on Block 9 (corresponding more to Block 8), and intimately connected with this is the presence of about 22 per cent. of the trees in a very marked "dwarf" group, shown in the di-modal form of the distribution curve. The planting on this block was very late in the season, and this "dwarf" group can no doubt be attributed to the retarding effect of drought, as already discussed for similar results on Block 6, (see this Journal Vol. 2. No. 1, p. 31.)

Mean height of trees in cover strips	...	100.8 inches.
Mean girth of trees in cover (at 3 ft.)	...	2.92 „
Mean height of trees under clean weeding		110.3 „
Mean girth of trees under clean weeding		3.23 „

On a single (additional) area of this block a mixed cover of Calopogonium, Centrosema and Vigna was planted in March 1929 and has grown well. The growth figures correspond with the other cover plots on the block, being;

Mean height	...	101.7 inches.
Mean girth	...	2.81 „

Block 11.

This block of 10 acres is an experiment on planting without clearing. Nothing was removed after the burn (July 1928) and all secondary growth was allowed to develop. Measures have since been taken to keep this in check, but nothing was done previous to taking the measurements considered here. Planting was carried out in January 1929, 5 acres (A) being planted at 22 ft. x 22ft. and 5 acres (B) at 22 ft. x 11 ft. The two halves were further subdivided and sections planted with seed at stake, basket plants and stumps. Analyses of the figures to compare the growth of the different planting material gave the following results shown in Table II.

TABLE II.

	Average height (inches.)	
	A.	B.
Seed at Stake ...	119.2	113.8
Baskets ...	136.3	123.7
Stumps ...	125.3	123.1
Average girth (all taken together)	3.55 ins.	3.27 ins.

Thus the growth compares favourably with other Blocks which received more conventional treatment, while basket plants again made the best growth. About 7 per cent. of the trees were supplied on A and 4 per cent. on B., indicating that the losses per acre were about the same.

Discussion.

The main effects to be expected in the above experimental plots may be classified as follows:—

Soil Moisture. The covers will lessen evaporation by their shading effect, but will also increase the demands for moisture by their transpiration. On balance the effect may be small. Reversion to belukar comes into the same category as covers. The lying timber will shade the soil, though to a much smaller extent than the belukar and so conserve moisture without any counter-balancing losses.

Plant Nutrients. Covers and belukar will compete with the trees for available nutrients. These are not, however, removed from the site, but are stored and can be made available in the future. The timber (Blocks 7 and 11) will ultimately supply considerable amounts of nutrients, and these will be released more quickly on the plots under a cover crop by reason of a more rapid decay. The exposed timber is constantly sterilised and dried by the sun, which retards decay.

Soil Temperature. The soil temperature is subject to much less fluctuation under the shade of covers and belukar, which may be regarded as a more natural condition for the trees. On the other hand the periods of high temperature on the clean weeded soil will have the effect of increasing micro-biological activity and producing quicker release of plant foods.

The main results are summarised in Table III, using values for same planting distance (22 ft. × 22 ft.)

TABLE III.

Average heights (ins.) attained at 18 months from planting.

	Best Growth.	Worst Growth.
Reversion to belukar	136.3	119.2
Under covers (with timber) ...	149.7	116.0
„ „ (surface cleared)	124.7	107.7
		100.8 (Block 10)
Clean weeded (with timber) ...	155.9	131.8
		139.9 (Block 9)
„ „ (surface cleared)	155.2	125.7
		142.9 (Block 9)
		110.3 (Block 10)

Under clean weeded conditions growth has been about the same with timber lying as with clean clearing. This would indicate that the benefits from moisture conservation and decay of timber under exposure to sun approximately balance the retarding effect of shading (on release of soil nutrients). On the other hand, where there is a cover present the lying timber is consistently beneficial, amounting to 12.8 per cent. on the average. This may be attributed to the decay of timber under protection of a cover, acting quite simply to reduce the effect of competition by increasing supplies of plant nutrients. Apparently decay has not been quite rapid enough to neutralise fully the effect of competition, for Table I shows the general effect of cover as reduced to a little less than one half by the presence of timber.

Clean weeding has in every instance been beneficial to growth. The ultimate benefit must, however, remain in some doubt as it is obviously gained (when compared with other plots) by sacrificing the conserving processes represented by soil shading and storage in the tissues of cover plants. Thus an advantage in the first years may easily pass into a disadvantage in later years.

There is one anomaly to be noticed in that the basket plants under clean weeded timber do not show the increase over the similar plot under cover which comparison with other cases would

lead one to expect. For seed at stake and for stumps the benefit from clean weeding (with timber) as against cover was over 13 per cent., but for basket plants was only 4 per cent. It is to be noted that the exception concerns the plots of maximum growth. It is difficult to avoid the suggestion that here we have reached the maximum growth under the conditions which are common to all plots. In other words, a limiting factor has come into play which is outside the conditions experimentally controlled, and so has prevented further response. One might even go further and raise the interesting question whether this limiting factor is the maximum potential growth rate of the tree. Such a maximum must undoubtedly exist, and has the highest importance for discussion because it sets the limit to the age at which Hevea could be brought into bearing under ideal conditions. Such ideal conditions are probably not attained on any plots at Sungei Buloh Experiment Station; the rainfall distribution alone cannot have been nearly ideal for growth. It is interesting to note that the growth on these "best" plots closely corresponds to the best growth under manuring on Block 6, so that there would appear to be some reality in this "maximum growth rate" for the particular site.

Summary.

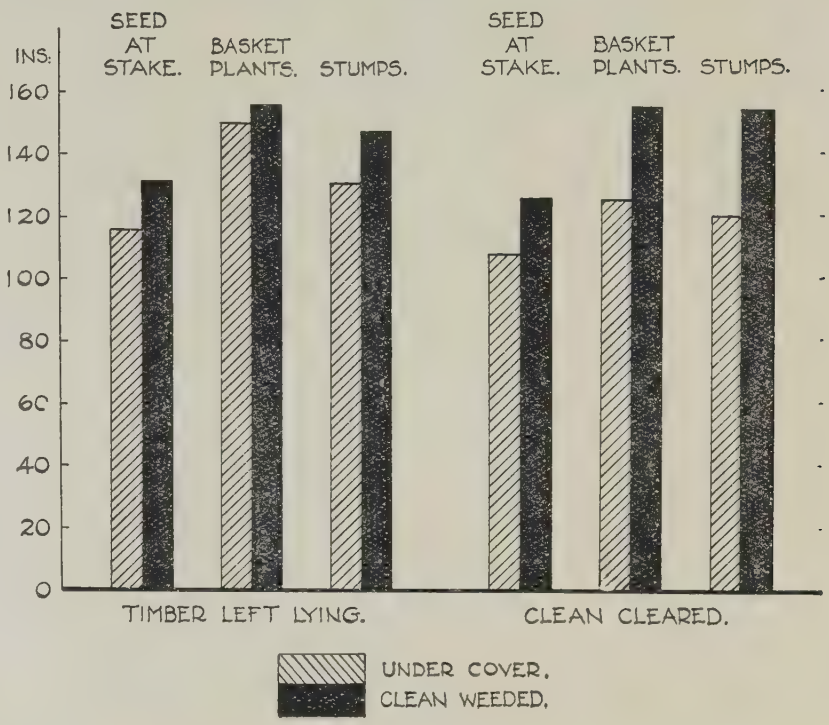
Comparisons of growth on Blocks 7, 8, 9, 10 and 11 at the Experiment Station at Sungei Buloh have been made on Hevea trees 18 months of age. The following conclusions are warranted from the results, but it is emphasised that their general application must be made with most cautious regard for other factors which may arise at later stages of development.

(1) Basket plants on the whole gave about 20 per cent. better results than seed at stake. Stumps were very slightly inferior to basket plants in spite of the apparent advantages which the former enjoy at the start.

(2) Clean weeded plots have consistently made better growth than those under cover. In one case of "optimum" growth the difference was small; in other cases the difference was about 23 per cent. for clean cleared land and 13 per cent. for land under timber.

(3) The effect of leaving timber lying has been decidedly beneficial. Where the area has been allowed to grow up into belukar the results are between those for cover and clean weeded plots on the cleared land. That is, planting under so-called "kampong" conditions has so far compared quite favourably with the more conventional methods.

GROWTH OF RUBBER 18 MONTHS FROM PLANTING.



STANDARD INSTRUCTIONS FOR THE PROTECTION OF PRUNED SURFACES IN BUDDING OPERATIONS.

BY

A. Sharples and C. E. T. Mann.

The budding operation should be undertaken preferably on young rubber trees from 12 to 18 months old. It is desirable to carry out the budding operation at as early an age as possible, so that when budding has been successfully accomplished, and the stock finally pruned, only a comparatively small wood surface from 1 to 1½ inches in diameter is exposed by the cutting. A small surface of this size is rapidly covered by the ingrowing callus. Healing may be completed in from six to nine months and there is no special necessity to lay emphasis on the matter of a protective covering.

While it is generally recognised that young seedling stocks are most easily worked, there are numerous instances where obstacles have arisen to delay the budding programme and the plants to be budded have attained the age of 2½ to 3 years before the operation has been undertaken.

When budding has been done successfully on a 2½ years old stock, the cutting back of the stock after budding exposes a surface, on normally grown trees, of 4 to 5 inches diameter. An exposed wood surface of such a size may not be covered by the ingrowing callus for years, and there seems to be a definite lack of understanding of the principles which govern the reasons for protecting these large exposed wood surfaces.

It is a well-known fact, to which attention has been called since budding was initiated as a plantation practice that, when the stock is cut back, die-back fungi of various types enter through the exposed wood surface if steps are not taken to prevent their entry by means of some protective material. The materials used in this connection at the present date seem to be very variable. In this article recommendations are given which should be considered as standard from which there should be no deviation.

Again, not only are the materials used for protecting the exposed wood surface very variable, but the actual method, in practice, of cutting back the stumps varies according to the ideas of different people interested in budding. This should not be so,

for there are sound reasons for following the general method which is given below.

Where budding has been done successfully on 2—3 years old stocks and the latter are cut back, it is usual to find that some attempt is made to protect the large wood surface exposed. For this purpose painting with a solution of Brunolinum, white lead paint mixed with linseed oil, or even simple dressings with wood tar, have been tried. Melted grafting wax or a tacky dressing such as Cargilineum, have also been used but most estates are now using an Asphaltum-Kerosene mixture described by Sutcliffe* and recommended by the Rubber Research Institute. Considerable success has attended the use of the latter mixture but even where this has been used there may still be a considerable amount of unsuspected damage, owing to the entry of "die-back" fungi through the supposedly well protected wood-surfaces of the cut snags.

The mode of entry is simply explained. After cutting back, the woody tissues of the stump begin to dry out owing to the developing scion absorbing the water supplied from the roots. As a result of the drying-out, the woody tissues of the snag contract and the cut surface shows small cracks or splits which, if not quickly attended to, allow the entry of die-back fungi. If such cracks are examined carefully it will be found that they are often filled with fine earth.

After entry through the cracks in the exposed wood surface the fungi grow rapidly downward into the tissues. If no measures are taken to check their growth, penetration into the main axis below the point of union with the scion may take place and the fungi may progress right down into the main tap-root, thus killing the plants outright. The progress of these fungi through the tissues may be accelerated in plants deficient in vigour, or on areas where plants lack condition owing to slight attacks from fungi such as *Fomes lignosus*.

Figures I, II and III show the sequence of events. The case illustrated is an example of budding done on a 2½ years old stock on which the snag had been cut back to within two inches of the height at which the bud had been inserted. The cutting back was done in August, and the cut surface was painted over with a solution of Brunolium. This painting would prevent the entry of any die-back fungi for some time, possibly three or four months. Figure No. 1 is a longitudinal section taken in the following April, which shows that the wood-rotting fungi have penetrated to a depth of 2½ inches, i.e. to the level of the bud-patch, in a short

* H. Sutcliffe. The Use of Asphalts and Bitumens on Estates. Quarterly Journal, Rubber Research Institute of Malaya, Vol. 2, No. 3, 1930.

space of time, probably not more than 4-5 months. If the rot is allowed to extend below the level of the bud-patch there is the obvious danger of ultimate penetration into the main axis with the subsequent total loss of the plant. Even if the rot is discovered before it enters the main axis, the complete removal of the rotting tissue, which is now necessary, is extremely difficult to accomplish satisfactorily. Figure No. II shows a horizontal section of the specimen shown in Figure No. I and Figure No. IV shows a dead tree suspected to be attacked by *Fomes lignosus,* but which was actually killed as a result of the wood-rotting fungi gaining an entry through the cut-end of the snag, growing into the main axis and so into the tap-root, with the resultant complete rotting of all the tissues of the tap-root.

It is not advisable in this article to make recommendations for treatment with regard to those estates on which the snags rotting away as described may be found. It will be far more satisfactory to deal with any particular case on its merits and estate managers who have carried out budding operations and later find the rotting of the snag tissues as described above, are invited to write for advice and treatment. Such a position should not arise if the following recommendations are carefully followed.

Recommendations for the Treatment of Buddings made on Stocks not more than 18 months old.

1. It is assumed that the budding has been done successfully and pruning has now to be undertaken. The following procedure is recommended.

(*a*) Ten days to a fortnight after opening the budding, the stock should be pruned back to within three to four inches above the level of the bud-patch. (Figure V).

(*b*) The wood surface exposed by this pruning requires protection. On the day following pruning, the cut surface should be fully covered by a layer of a mixture made up of Asphaltum 2 parts and Kerosene 1 part. This mixture is smeared over the cut surface with the fingers.

(*c*) Given normal growth, after about six months, the lower portion of the scion shoot shows the development of brown bark to a height of about 2 feet from the union. At this stage, the second and final pruning of the stock should be carried out. The level at which the second pruning should take place is usually self-evident. A distinct external ridge marks the limit of living wood, (Figures V and VI at A) and the pruning cut should be made at this limit of living tissue marked by the

external ridge, so as to remove all dead or moribund tissue above.

(*d*) This newly exposed wood surface must again be protected. The procedure is slightly different from that suggested above for the first pruning. Immediately after the pruning is done, the coolie performing the operation should paint the fresh cut with either a 20 per cent. solution of Agrisol or Brunolinum Plantarium, both of which substances are water miscible. This protective painting will prevent any possibility of spores of the various die-back fungi germinating on the cut surface overnight. On the following day the cut surface is covered as before with a complete layer of the Asphaltum-Kerosene mixture.

II. *Recommendations for Treatment of Buddings on Stocks older than 18 months.*

The following procedure is recommended:—

(*a*) From ten days to a fortnight after "opening" the budding, the stock should be pruned off at a height of 6 to 8 inches, or even higher, above the top of the bud-patch, with a sloping cut at an angle of about 30° (c.f. Buddings on younger trees). (Fig. VI).

(*b*) The exposed wood surface requires protection. On the day after the pruning the surface should be completely covered with the Asphaltum-Kerosene mixture as explained above. However, there is a danger, some time after the bud-shoot comes away, of the Asphaltum-layer cracking owing to the drying out and splitting of the woody tissues immediately beneath the protective layer. Splitting of the Asphaltum layer should be taken as an absolute criterion that the cut ends of the snags require further treatment and all surfaces showing splitting should be re-treated immediately with a more fluid Asphaltum-Kerosene mixture containing Asphaltum 1 part, Kerosene 1 part. Such re-treatment could be easily undertaken by the labourers employed on the frequent pruning inspections which are so necessary for young buddings in the first year.

(*c*) The second pruning is undertaken as soon as the oldest portions of the scions show brown bark to a height of about 2 feet. The point of the final pruning is indicated by an external ridge of tissue (Figure VI at A). It is

of importance to note that this external ridge of tissue on stumps more than 2 years old is generally higher on the side of the stock on which the bud is grafted so that a sloping cut must generally be made to remove dead tissue. (Figs. VII and VIII).

(*d*) Painting with the Agrisol or Brunolinum mixture and the application of the Asphaltum-Kerosene mixture is carried out as recommended for buddings made on smaller stocks (Sec. I.d). It is essential that the protective Asphaltum-Kerosene layer should be maintained unbroken until callusing over of the exposed wood surface is completed. The more fluid Asphaltum-Kerosene mixture already mentioned is recommended for this purpose.

The details of the treatments given above should be considered as standard recommendations and should be followed rigorously. Exceptional cases are bound to occur and these should be notified to the Institute when they will be dealt with individually; also cases which have been recently budded and which now show rotting snag tissues should be notified to the Institute as these also require individual attention.

Explanation of Figures.

Figure I: Longitudinal section through a snag of a stock of 2½ years of age showing depth of penetration of "Die-back" fungi which have entered through cracks that have developed since the cut surface was treated with a disinfectant mixture. There was no surface indication of the rot beyond radiating cracks which appeared owing to drying out of the tissues.

Figure II: Transverse section of specimen shown in Figure I.

Figure III: Typical specimen of a snag on a stock grafted at 18 months old. The small amount of decayed tissue as shown in the drawing can be neglected for if the graft has developed vigorously the weakly parasitic "Die-back" fungi cannot make further progress and are ultimately cut out naturally.

Figure IV: Longitudinal section of tap-root of a 2½ year old bud-graft, showing the whole of the root tissues disintegrated by "Die-back" fungi which had entered via the snag.

Figure V: Illustrates the first cutting back of snag on 12—18 months old stock. Note external ridge of tissue at "A" indicating limits of living tissue.

Figure VI: Illustrates the first cutting back of snag on stocks 2½ years old or over. Note difference of length of snag left after the first pruning (c.f. Fig. V).

Figures VII and VIII: Illustrates the position where the second and final pruning should be made and slope of cut, on stocks of 12—13 months of age (Fig. VII) (b) on older stocks (Fig. VIII).

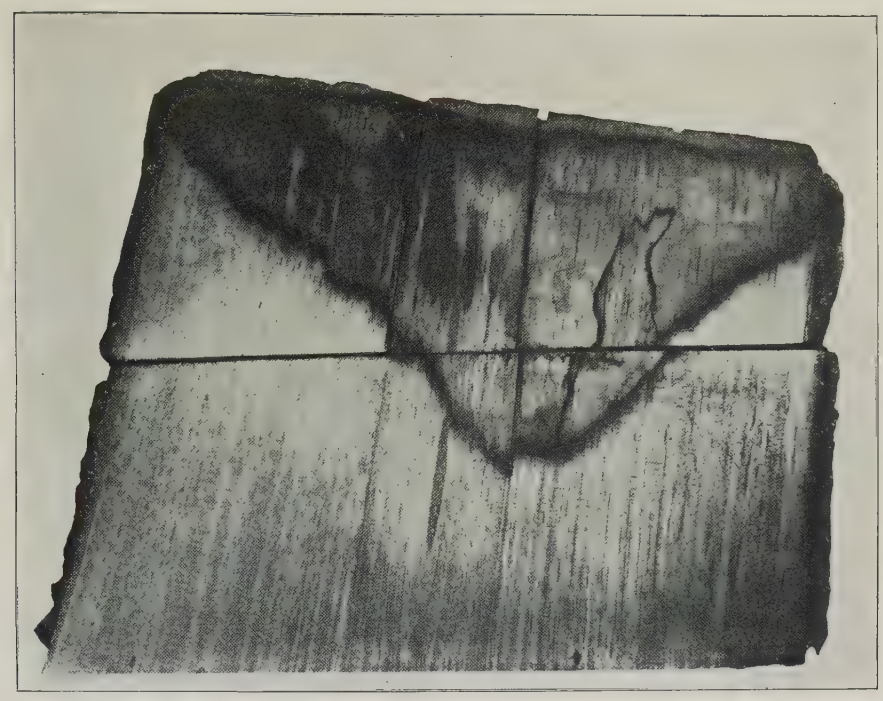


FIGURE I.

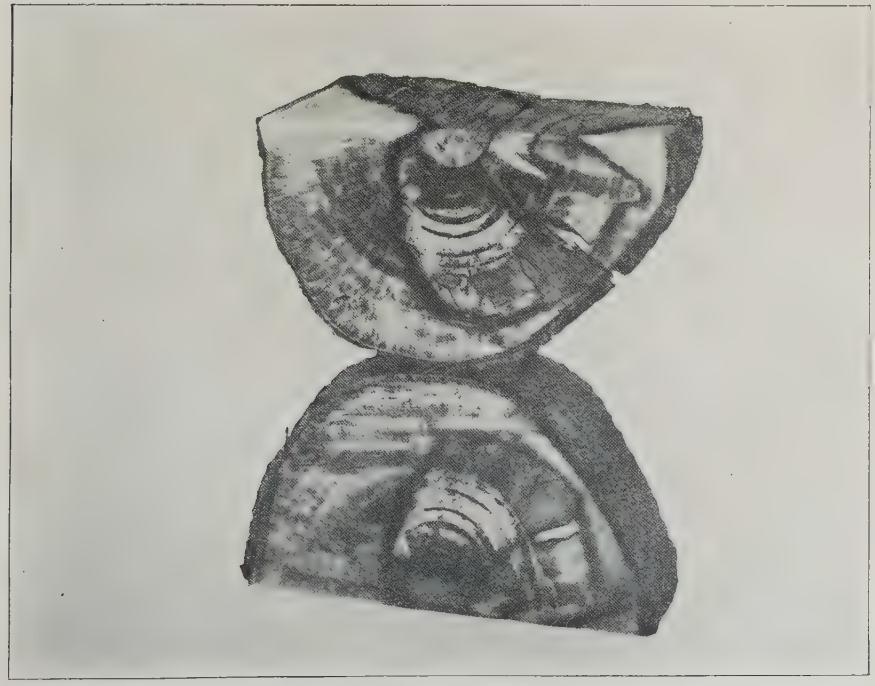


FIGURE II.

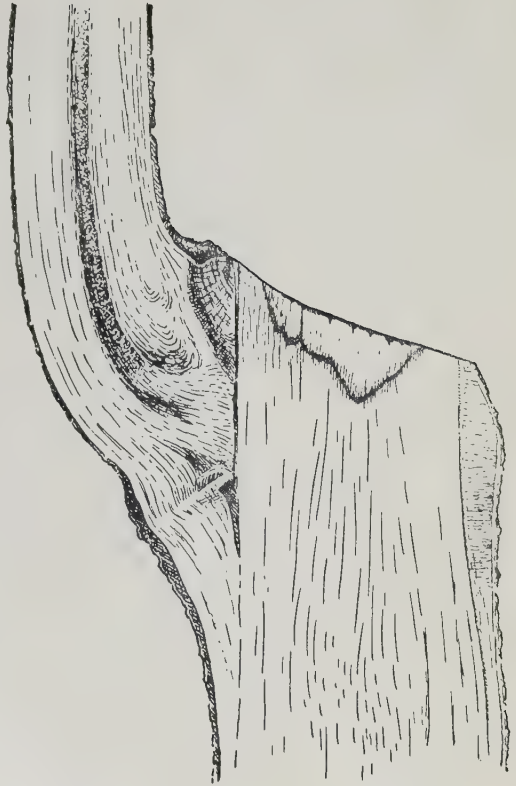


FIGURE III.

FIGURE IV.

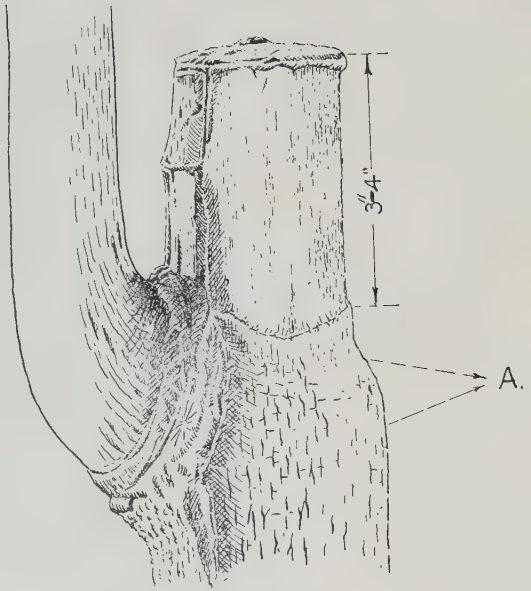


FIGURE V.

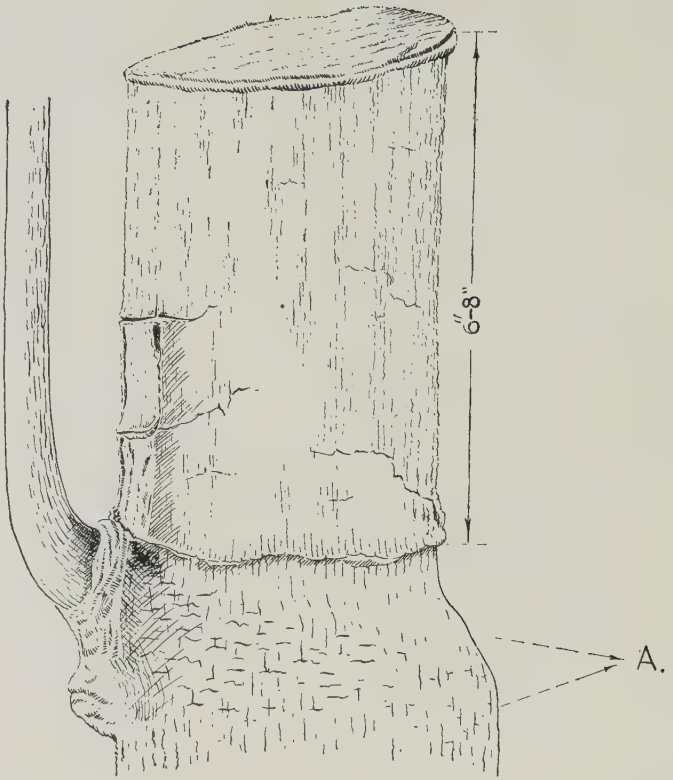


FIGURE VI.

FIGURE VII.

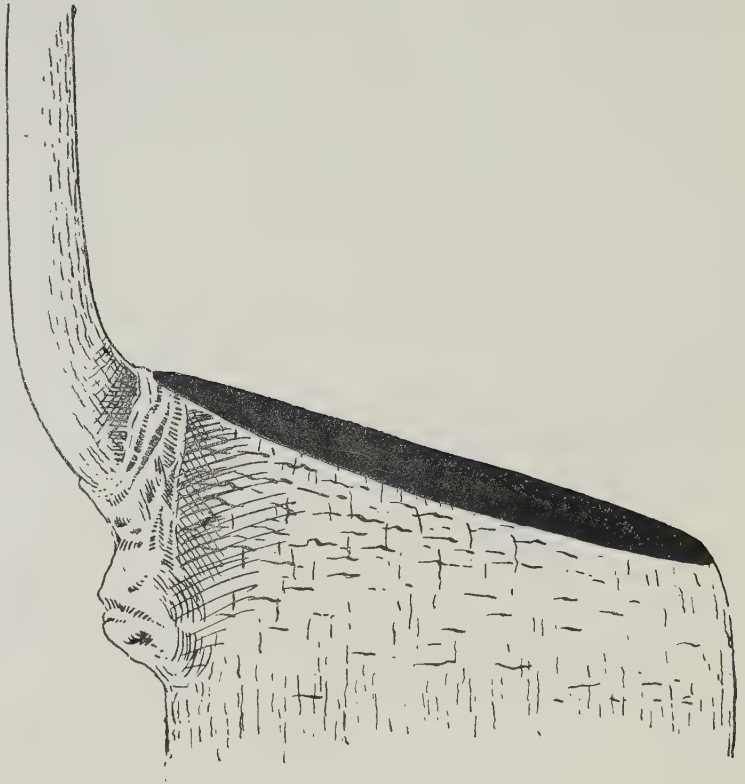


FIGURE VIII.

THE HEUSSER SYSTEM OF DOUBLE TAPPING AS APPLIED TO PRANG BESAR CLONES.

BY

R. J. CHITTENDEN.

After a visit to Sumatra where Heusser's tapping system was seen a similar experiment was started on Prang Besar Estate in April 1929. Despite differences in environment and material the results are similar to those obtained by Heusser.

Material.—The Prang Besar clones 23, 24, 98 and 186 were used. Later in 1930 the experiment was extended to include clones 159, 180 and 183. The results obtained on the first four clones only, are described here.

Methods.—The previous tapping history is shown in the diagram. Shaded areas indicate first renewal, black areas indicate second renewal.

Trees were opened on two quarter-cuts, two third-cuts, and two half-cuts, one of the two cuts being at 40 inches and one at 80 inches. The disposition of the cuts in relation to the previous tapping panel and to each other is shown in the diagram. It is possible that the renewal on the previous panel has somewhat interfered with yields, particularly those from two half-cuts.

Ten trees were tapped on each length of tapping cut; tapping was alternate daily; latex from the upper and lower cuts was collected separately. In P.B. 23, 5 trees formed a unit.

The trees selected are of the same age as those in ordinary test tapping on a single half-cut.

Trees of clones P.B. 23, 24, 98 and 186 were selected and put on to different lengths of tapping cut at random.

Girth.—A table of girth measurements in given below. It will be noted that, meagre though the figures are, there is less increase in girth on a double than on a single tapping system, and also that trees on two quarter-cuts appear to increase in girth more rapidly than those on longer cuts.

The extra increase in girth on trees on a single half-cut may perhaps be influenced by the fact that these trees are measured over the present tapping panel. A 'bulge' (an area of increased activity of growth) often follows the tapping cut down the trunk in buddings.

GIRTH IN CMS.

	Two Half-Cuts.			Two Third-Cuts.			Two Quarter-Cuts.			Single Half-Cut.		
	1930			1930			1930			1930		
Clone.	March.	Sept.	Increase.	March.	Sept.	Increase.	March.	Sept.	Increase	Feb.	Aug.	Increase.
98	59.3	61.0	1.7	61.5	63.8	2.3	64.5	67.1	2.6	68.8	72.2	3.4
24							74.3	78.1	3.8	77.6	82.9	5.3
186	77.0	80.6	3.6	77.0	80.6	3.6	80.8	84.9	4.1	78.6	84.8	6.2
23							79.3	81.1	1.8	74.4	77.6	3.2

Yields.—These will be found in Table I. At first, owing to the difficulty of ensuring accuracy in collection, attention was confined to collecting the No. 1 latex only; later when the coolies were sufficiently accustomed to the work, scrap and lump were also harvested. Similarly records were not kept till May 1929 by which time collection was satisfactorily accurate.

YIELDS PER UNIT LENGTH OF CUT.

a. The yield per unit length of cut appears to be higher, the shorter the cut (this agrees with Maas, Arch. voor de Rubbercultuur 25).

b. When total dry rubber is considered, trees on two quarter-cuts (with the exception of P.B. 98) yield more per unit length of cut than those on a single half-cut. With the exception of P.B. 23 they (trees on two quarter-cuts) yield less No.1 rubber per unit length of cut than those on a single half-cut.

THE RELATION OF THE YIELD OF THE UPPER CUT TO THAT OF THE LOWER.

The lower cut yields more than the upper cut; usually, the shorter the cut the higher the yield of the upper cut in relation to that of the lower cut.

Further the relation which the yield of the upper cut bears to that of the lower cut varies with the different clones. In P.B. 186 on two quarters the upper cut gives 80 per cent. of the yield of the lower cut whereas in P.B. 24 the upper cut only gives about 60 per cent. of the yield of the lower cut.

This difference between the clones seems to be closely correlated with the number of latex vessel rows at the various heights of tapping (see Table II).

TABLE I.

Analysis of Results obtained from Test Tapping on a Single-Cut and on Double-Cuts.

Yield of No. 1 Rubber in Gms. per Tree per Tapping.

Clones	Two Half-Cuts						Two Third-Cuts						Two Quarter-Cuts						Single Half-Cut				
	Upper Cut		Lower Cut		Both Cuts		Upper Cut		Lower Cut		Both Cuts		Upper Cut		Lower Cut		Both Cuts						
	No. 1 Rubber.	Scrap	No. 1 Rubber.	Scrap	Total No. 1	Total No. 1 & Scrap	No. 1 Rubber.	Scrap	No. 1 Rubber.	Scrap	Total No. 1	Total No. 1 & Scrap	No. 1 Rubber.	Scrap	No. 1 Rubber.	Scrap	Total No. 1.	Total No. 1 & Scrap	No. 1 Rubber.	Scrap	Total No. 1 & Scrap		
186	30.8		40.8		71.6		23.5		29.2		52.7		22.2		26.9		49.1		51.5			May	1929—Nov. 1930
98	16.9		27.5		44.4		13.7		22.1		35.8		14.1		19.7		33.8		35.9			„	„
23													19.2		27.7		46.8		44.5			„	„
24													15.6		27.0		42.6		44.3			„	„
186	32.4	4.7	40.9	4.0	73.3	82.0	24.4	2.7	30.0	2.1	54.4	59.2	24.0	2.1	29.1	2.1	53.1	57.4	55.1	1.2	56.2	Dec.	1929—Nov. 1930
98	15.8	1.3	27.8	1.3	43.7	46.2	12.6	1.0	22.3	1.0	34.8	36.8	13.2	.9	19.6	.9	32.8	34.5	36.8	1.1	37.9	„	„
23													20.2	3.4	29.2	2.9	49.3	55.7	44.8	1.6	46.5	„	„
24													17.3	2.3	28.9	1.7	46.2	50.3	46.7	1.9	48.6	„	„

TABLE I.—(Contd.)

Percentage Dry Rubber Content of Latex.

Clones	Two Half-Cuts			Two Third-Cuts			Two Quarter-Cuts			Single Half-Cut	
	Upper Cut	Lower Cut	Upper & Lower Cuts combined	Upper Cut	Lower Cut	Upper & Lower Cuts combined	Upper Cut	Lower Cut	Upper & Lower Cuts combined		
186	32.5	29.9	30.9	32.9	33.0	33.0	35.6	35.1	35.4	36.0	May 1929—Nov. 1930
98	27.3	29.2	28.5	30.7	33.2	32.1	35.1	36.9	35.7	36.2	,, ,,
23							32.2	33.4	32.9	22.6	,, ,,
24							33.3	33.5	33.4	35.3	,, ,,
186	32.3	29.3	30.5	32.4	32.4	32.4	35.7	35.1	35.4	35.9	Dec. 1929—Nov. 1930
98	27.8	29.8	29.1	31.4	34.0	32.9	34.9	37.6	36.5	36.0	,, ,,
23							31.8	32.7	32.4	33.0	,, ,,
24							33.7	33.5	33.6	35.9	,, ,,

Scrap as a Percentage of No. 1 Rubber.

Clones	Two Half-Cuts			Two Third-Cuts			Two Quarter-Cuts			Single Half-Cut	
	Upper Cut	Lewer Cut	Upper & Lower Cuts combined	Upper Cut	Lower Cut	Upper & Lower Cuts combined	Upper Cut	Lower Cut	Upper & Lower Cuts combined		
186	14.6	9.7	11.9	10.9	7.1	8.8	9.1	7.2	8.1	2.1	Dec. 1929—Nov. 1930
98	8.2	4.6	5.9	7.3	4.4	5.6	6.4	4.5	5.3	3.0	,, ,,
23							16.8	10.0	12.8	3.7	,, ,,
24							13.3	6.0	8.8	4.2	,, ,,

TABLE II.

The Yield of the Upper Cut expressed as a Percentage of the Yield of the Lower Cut.

Clone.	No. 1 Rubber (May '29—Nov. '30.) Two ½ Cuts.	Two ⅓ Cuts.	Two ¼ Cuts.	Total Dry Rubber (Dec. '29—Nov. '30.) Two ½ Cuts.	Two ⅓ Cuts.	Two ¼ Cuts.
186	75.5	80.5	82.5	82.6	84.6	84.0
98	61.5	62.0	71.6	58.8	58.4	68.8
23			69.3			73.5
24			57.8			64.1

Latex Vessel Counts on Double Tapping.

Clone.	Field.	Tree No.	Date of Budding.	Date of taking bark sample.	No. of Latex vessel rows at 80 ins.	No. of Latex vessel rows at 20 ins.
23	7	705	June 1923	12.10.1929	27	30—33
186	4	1468	April 1922	12.10.1929	21—22	21—22
180	4	0852	April 1922	20. 6.1930	12—13	19
24	17	386	Dec. 1922	12.10.1929	15—18	23—27
183	10	1241	June 1923	20. 6.1930	13—16	19—23
98	15	1637	Oct. 1922	12.10.1930	10—11	12—14

Total Number of Tapping Days.

	May 1929—Nov. 1930. Single Cut.	Two Cuts.			May 1929—Nov. 1930. Single Cut.	Two Cuts.		
Clone.	½	½	⅓	¼	½	½	⅓	¼
186	254	253	253	255	167	166	166	168
		(*a*)	(*b*)					
23	253	(101)	(115)	254	166	14	28	167
98	255	253	252	252	166	164	163	163
		(*a*)	(*b*)					
24	256	(101)	(114)	254	166	13	25	166

(*a*) May 1929 to December 1929 only.

(*b*) May 1929 to January 1930 only.

Wintering.—It should be noted that on double tapped trees of P.B. 23 and 186 the drop in yield over wintering is not so pronounced as on trees on a single half-cut, and is in fact very slight indeed.

Yields: Scrap and Lump.—In all cases double tapping leads to an increase in the amount of scrap obtained as compared with that from a single half-cut. In P.B. 98 the increase in the amount of scrap is no larger than might perhaps be expected from the extra cups, spouts and channels in use, but in the other clones there is a significant increase, the double cut system tending to later dripping; this is particularly marked in P.B. 186.

There is an increase in the amount of scrap with an increase in length of tapping cut though the yield per unit of cut remains about the same. Except in the case of P.B. 98, there has been a drop in the amount of scrap obtained as the experiment progressed(this is in some cases associated with a drop in yield.)

Except in the case of P.B. 98 the yield of scrap from the higher cut is greater than that from the lower cut.

Dry Rubber Content of Latex.—The dry rubber content of the latex decreases with an increase in the length of cut. It is also, except in P.B. 98, lower on two quarter-cuts than on a single half-cut though this difference is usually slight.

With the exception of P.B. 186 the dry rubber content of the lower cut is either about the same as or higher than that of the upper cut.

The drop in the dry rubber content of latex from the various cuts on different clones is only marked on the third and half cuts in the case of P.B. 23 and 24. These lengths of cuts, as might be expected in view of the drop in the dry rubber content, proved too heavy for those two clones; Brown Bast occurred frequently and the tapping of P.B. 23 and 24 on two half and on two third-cuts was stopped.

Brown Bast.—In trees affected by Brown Bast on double tapping usually the upper and lower or the lower cut alone are affected, rarely the upper cut only. No Brown Bast has been observed on trees on two quarter-cuts.

Comments.—The close agreement between these results and those already published by the AVROS Proefstation (where this system originated) is noteworthy. It would be somewhat premature to draw any definite conclusions from our results; the indications however are as follows :—

1. Clones P.B. 23 and 24 can probably not be submitted to a system of any greater severity than a single half-cut alternate daily.

2. Clones P.B. 186 and 98 might sustain a heavier tapping system than that to which they are at present subjected, since both withstood tapping on two half-cuts for 20 months.

The somewhat drastic system of two half and two third-cuts was stopped at the end of Nov. 30 from motives of economy in test-tapping.

3. Clone P.B. 23 appears to respond particularly well to two cuts on a quarter, yielding at the rate of over 3 lbs. per tree more than on a single half-cut.

General.—The Heusser system appears to be particularly suitable since the latex zones tapped by each cut do not over-lap and there is a free circulation of sap to the respective cuts. Slight disadvantages appear to be that possibly girth increase is not so rapid on trees on a double tapping system and that ladders are necessary for tapping. With regard to the latter disadvantage experiments are now in progress on Prang Besar Estate in which the cuts are brought lower down the tree and closer together. So far no deleterious effects have been observed from this approximation of the cuts and the ladder has been dispensed with.

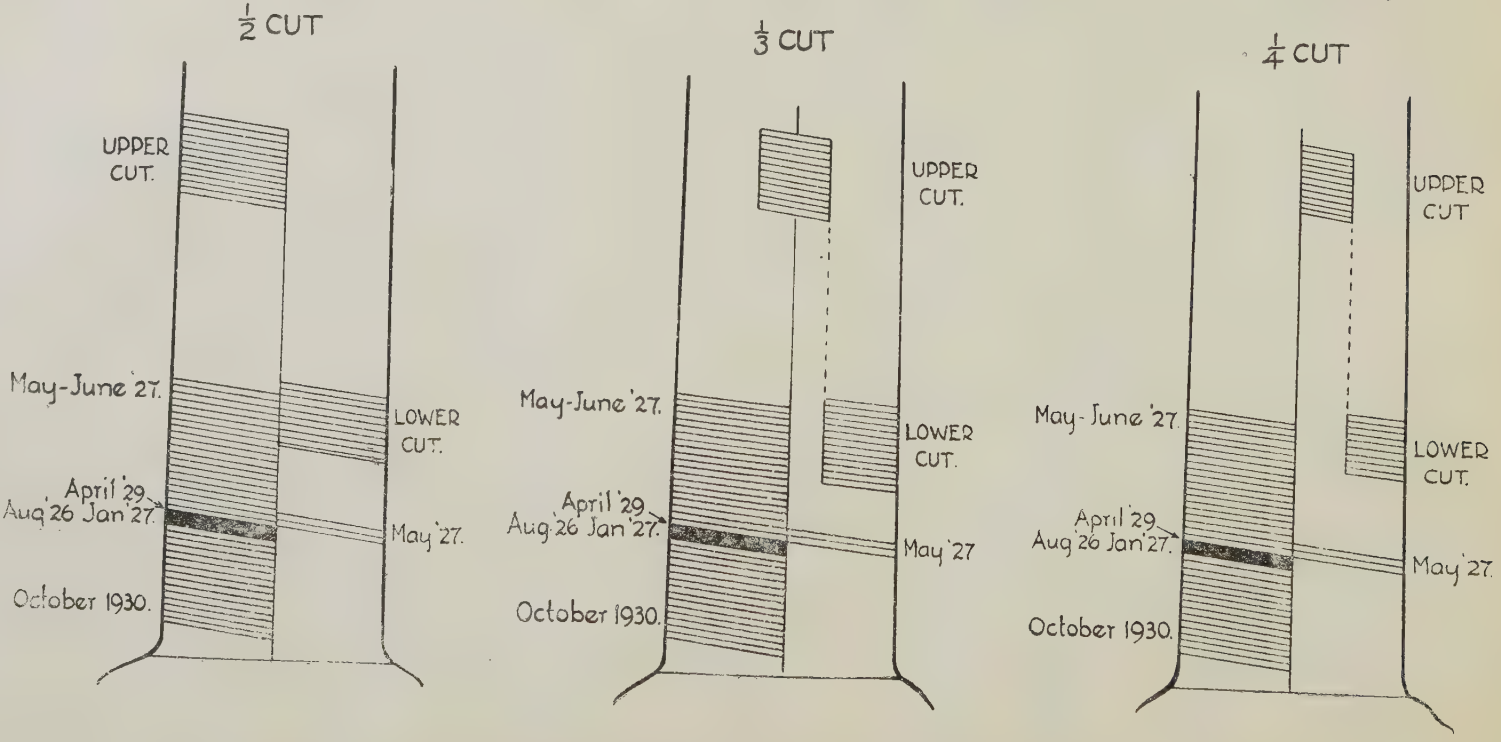
References.

(1) Heusser, Dr. C. and Holder, H. J. V. S. "Experiments with a new tapping system of Hevea-budgrafts." Arch. v.d. Rubbercultuur, July, 1929.

(2) Schmole, J. F. and Prummel, B. "Tapping experiments with two cuts on Hevea buddings." Arch. v.d. Rubbercultuur, April, 1930.

(3) Heusser, Dr. C. and Holder, H. J. V. S. "Tapping results with the new double cut tapping system on Hevea buddings." Arch. v.d. Rubbercultuur, July, 1930.

DIAGRAM SHOWING THE PANELS PREVIOUSLY TAPPED ON ½ CUT AND THE POSITION OF THE STEPPED (½, ⅓ & ¼) CUTS.
SHADED AREAS SHOW FIRST RENEWAL, BLACK AREAS SECOND RENEWAL.



FURTHER OBSERVATIONS ON PLANTING SYSTEMS FOR BUDDING OF TESTED CLONES.

BY

C. E. T. Mann.

In a previous number of this Journal* a short review of the position regarding the planting of buddings of "proved" clones was given. Since the publication of that review, further study and the collection of further data from tapping experiments on budded trees, make it possible to discuss more fully certain principles which govern planting policy when the planting material consists of buddings of well tested clones.

The distribution of buddings of different clones in a new planting, or in re-planting, will be determined to a great extent by the choice of clones and will depend mainly on the age of the clones selected. The age of a clone is reckoned from the time of planting of the first set of buddings from the selected parent tree or "mother tree." The older the clone the longer will be its history of performance and the more certain will be the knowledge of secondary characters in addition to yielding capacity.

During the past three years many suggestions for the best utilisation of buddings of the known high yielding clones have been made on the basis of which a number of different planting systems have been evolved. The main proposals can be broadly classified as :—

I. Block or monoclone planting, using only the most desirable of the oldest, tested clones.

II. Mixed planting, using buddings of a number of promising clones, mixed in the same area in equal proportions.

III. Mixed planting in which the principles underlying I and II are combined. Half of the planting consists of buddings of a single well tested clone and alternate plants are buddings of one, or more promising clones not yet sufficiently well tested for monoclone planting.

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* Mann, C. E. T. "A Short Review of the Present Position of the Planting of Buddings of Proved Clones," Quarterly Journal, Rubber Research Institute, Vol. 1, No. 4, 1929.

I. Block or Monoclone Planting.

The advantages claimed for this system are:—

(1) Simplicity in establishment and control.

(2) The optimum density of trees can be maintained, and the maximum yield per acre obtained, for each clone.

(3) The system of tapping found by experiment to be the most suitable can be applied to the trees of each clone without difficulty.

(4) The uniformity of the material should result in perfect tapping and satisfactory bark renewal.

(5) In the event of a clone, satisfactory in all other respects, showing particular susceptibility to a specific disease, control of the disease in a pure planting will be relatively simple, probably more successful and certainly less costly than in a mixed planting.

(6) Should a clone show symptoms of a serious fault within the first two, or possibly three years after planting successful re-budding with a superior clone might be carried out.

(7) The system provides for the possibility of economic replanting in the event of a particular clone developing defects at maturity which render it unprofitable.

(8) It is possible that seed taken from the trees in the centre of a pure planting may have a considerable ultimate value. The value of seed may be increased by establishing a small number of trees of a superior seed-parent clone in the centres of fairly large areas planted with single clones.

The objections raised against block planting are:—

(1) Sufficient information is not yet available concerning any of the tested clones to eliminate completely the possibility of their ultimate failure to maintain satisfactory qualities in later years.

(2) In block planting only the oldest tested clones can be used and many promising newer clones must be passed over for the time being, even though they show indications of a greater yielding capacity than the older clones when they reach comparable age.

(3) Different clones show individual differences in the quality of their latices and difficulties in manufacture are likely to arise in dealing with large volumes of latex from single clones.

II. Mixed Planting.

Using equal numbers of buddings of a number of different clones thoroughly intermixed in the same area.

The advantages claimed for mixed planting are:—

(1) The best of the oldest clones and the most promising of the newer clones may be established together without undue risk.

(2) Thinning may be done systematically on the basis of the performance of the oldest trees of the clones represented in the new planting. Time will thus be saved in establishing new clones in commercial planting.

(3) The fact that the different clones do not "winter" together or to the same degree will have the effect of evening-up the crops obtained over the wintering season.

(4) From mixed budded areas the latex reaching the factory will be averaged and should give no difficulty in manufacture. Rubber of normal, uniform quality will be obtained.

The disadvantages of the system are:—

(1) In establishment, even distribution of each clone must be arranged, therefore expensive supervision and control are required.

(2) To ensure that a sufficiently large stand of trees per acre will remain after the elimination of unsatisfactory clones the initial density must be high.

(3) Clones differ considerably in vigour and habit; a vigorous, spreading tree may easily impair the growth of neighbouring, less vigorous trees, even though the latter may be potentially the better producers.

(4) The advantages of selective thinning on the basis of continued study of the performance of the oldest members of a clone are strictly limited. It may quite well happen that drastic removal of trees in a mixed area may become necessary before the oldest tested buddings of any of the clones used have developed undesirable traits or have yet yielded sufficient fresh information as to their productive capacity to show significant differences between each other. Underlying all thinning that has to be done at such a stage will be the feeling of uncertainty as to whether the least desirable trees are being removed. Eventually,

one or more clones may show signs of becoming uneconomic but by that time the optimum stand of trees per acre will probably have been reached, and the prospect of progressively falling crops will have to be faced.

(5) The optimum tapping system for any single clone cannot be applied and therefore the maximum crop, consistent with the health of the trees, will not be obtained.

(6) The control of disease, especially specific troubles to which certain clones may be particularly susceptible, will be increased in difficulty and cost.

(7) Seed taken from mixed areas will probably be of less value than seed taken from the centres of pure plantings.

III. Mixed Planting.

(In which half of the planting material consists of a single well tested clone and the other half of buddings of one, or more, promising new clones).

(a) The advantages of using one well tested clone with one new promising clone.

(1) There is no loss of time in establishing, in commercial planting, a new clone which promises to give a greater return than any of the oldest tested clones known at present.

(2) Further data from the study of the oldest members of the clones will determine which of the clones should be eliminated.

(3) The ultimate result of the elimination of either clone will be a monoclone planting of a well tested clone and the disadvantages of mixing are avoided.

(b) Advantages of using one well tested clone with a number of newer promising clones.

(1) and (2) The same remarks apply as for (a) (1) and (2) above.

(3) Should none of the new clones prove superior to the oldest tested clone used then a pure planting of a reliable clone will result.

(4) Should one or more of the newer clones prove superior to the old clone, then the result will be a mixed budded area capable of a greater production than an area planted with the single tested clone.

The main objections to the above systems are:—

(1) Except that a high density of trees may have to be maintained for a considerable period the objections to (a) are only those which concern the possible difficulties which may be encountered in manufacture with latex from pure plantings.

(2) When more than one clone is finally retained (b) the objections already raised against mixed planting (II) again apply.

Discussion.

As far as possible, the main points for and against the chief systems at present in use in the planting of buddings of tested clones have been presented and there appears to be a strong case in favour of block or monoclone planting.

The main objection to block planting appears to rest on the assertion that none of the "proved" clones at present known have been under observation for a sufficiently long period to eliminate all chance of ultimate failure to maintain satisfactory performance.

The oldest tested clones are entering their fourteenth year, several are in their eleventh year and many of the promising younger clones are in their ninth year of age. Though it is true that the history of even the oldest clones is still incomplete, yet the satisfactory records of normal tapping extending over seven years and including periods of tapping on renewed bark constitute a reasonable assurance that budded trees of the best clones are likely to continue to behave normally in their response to the usual treatments. The objection to monoclone planting on the grounds of incomplete knowledge of the full history of a clone might be applied with equal force to any system of planting in which buddings are used.

When the value of *Hevea brasiliensis* as a plantation crop was first realised, although the life of a rubber tree under plantation conditions was a subject of speculation, planters willingly risked the establishment of large areas of the promising new crop. Monoclone planting of buddings of well tested clones may be regarded in a somewhat similar light.

In the oldest plantations signs of deterioration of the trees are evident but even in the worst areas certain trees can still be found in a vigorous productive condition. Individual trees appear to show considerable variation in the rate of decline under plantation conditions and since clones exhibit many of the characters of the parent trees from which they spring it is reasonably

certain that different clones will deteriorate at different rates. It is therefore quite conceivable that in a mixed area the trees of some clones may become unprofitable some years before signs of deterioration are evident in other clones. The total production of the area may fall below the economic limit in consequence. Re-planting may be the only solution of the problem and profitable trees of the better clones will have to be removed. This wastage could have been avoided had the original planting been on the monoclone system.

The objection to monoclone planting on the ground that latex from a single clone may present special difficulties in manufacture and possibly give an inferior product seems to require further supporting evidence. It is conceivable that latex from a single clone may even give a superior product. In any event it should prove relatively simple to arrange to treat in the factory a mixture of latex from the different clone blocks which will be comparable with the mixed latex which would be obtained from a mixed area containing the same clones.

By adopting the monoclone planting system the possibility of using promising newer clones is not necessarily eliminated though this is frequently claimed to be a defect of this system. The simple modification, suggested in III, of planting a "safe" clone with a new clone overcomes the difficulty.

Conclusions.

The advantages of the block or monoclone system of planting as applied to the oldest tested clones, considerably outweigh the disadvantages. It is therefore recommended that clones having a continuous and satisfactory tapping history extending over five years or more, during which time observations on secondary characters have revealed no defects in other respects, should be planted on the monoclone or block system.

When it is desired to use younger clones of considerable promise, that have been under test for less than five years, the planting of blocks containing equal numbers of buddings of one of the oldest clones alternating with buddings of the new clone is recommended. Such plantings will be ultimately developed as monoclone plantings as soon as it is possible to decide upon the relative merits of the two clones.

In circumstances where choice is restricted to newer clones mixed planting of a number of different clones must still be advised and though the ultimate production of such plantings may be entirely satisfactory, in comparison with pure plantings, maintenance and control are likely to be more difficult and expensive.

EDITORIAL.

Manurial Experiments.

During the last four years a considerable number of manurial experiments on rubber areas have been carried out on various estates in Malaya, as well as in Sumatra and Java.

This Journal contains a résumé of the results obtained which have been analysed statistically by Dr. Haines and Dr. Flint of the Soils Division of the Institute.

A number of the experiments carried out on estates in Malaya have been laid down in accordance with the recommendations of the Soils Division of this Institute, while the results from all the experiments quoted have been critically examined and discussed by the authors.

It will be seen that the proportion of uncertain results, that is, results in which no increases of yield have been obtained, renders it impossible at present to recommend a manuring programme on a large scale with the certainty of economic success.

Areas yielding over 400 lbs. of rubber per acre per annum do not usually respond to manurial treatment, while those yielding under 300 lbs. per acre per annum may be expected to show satisfactory increases.

From an economic aspect, however, the problem of manuring is obviously related closely to the market price of raw rubber, but, since the rubber tree is a "permanent" crop, the question of the ultimate deterioration of the trees and decrease in yield of latex must be borne in mind.

The results also show that in many cases of poor yielding areas on which the trees also exhibit poor vegetative characters, the first response to manurial treatment will be in the development of a more satisfactory foliage, the arrest of die-back and the improvement in bark renewal, while any effect on yield of latex may be considerably delayed. As would have been anticipated from our knowledge of the deterioration of soils in a humid tropical climate, after the clearing of jungle and followed by a policy of clean-weeding, the principal soil nutrient which would show a deficiency would be nitrogen due to the "burning out" or oxidation of the organic matter (humus) in the surface layers of the soil. This is confirmed generally by the response shown to manurial treatment with nitrogenous fertilizers. Evidence is however accumulating which indicates that the fertility of a soil under rubber cultivation can be maintained by the growing of leguminous cover crops or by means of selective weeding during the early stages, which not only prevents or retards the destruction

of the valuable humus in the surface soil, but also locks up the nitrogen in this humus, which otherwise is readily oxidised and leached from the soil.

The planting of budded rubber, resulting in considerably higher yields of latex, may however render the use of fertilizers not only essential but also give greater economic success.

The above and other important aspects of the problem are illustrated in the discussion by the authors, which is included in the article.

In addition the authors also discuss, in another article, describing the results of manurial treatment on Block 6 at the Institute Experiment Station, the problem of manuring of young rubber.

In this paper, it is shown that the only significant result so far obtained has been the slight improvement in vegetative growth and vigour, as measured by girth and height and branch development, due to the application of cattle manure. The results indicate that the virgin jungle soil on the area has sufficient reserves for the earlier stages of the growth of the trees. It may, however, be found later, that the control plots as well as the plots to which no nitrogen has been added, will deteriorate, both in respect of vegetative growth and yield of latex, especially since the plots are all clean-weeded.

Effect of Covers v. Clean-weeding.

A continuation of the article on "The Effect of Covers and Clearing Methods on the Growth of Young Rubber Trees" published in this Journal (Vol. 3, No. 1) confirms the anticipation expressed in the previous article, viz. that the trees on the plots under various covers, which were retarded in growth at a younger age, are now catching up in growth the trees on the clean-weeded plots, probably due both to the root development of the trees which have extended to depths in which they no longer compete with the cover crops and also to the fact that the humus in the clean-weeded plots is being reduced.

Later results on both the manurial treatments on Block 6 and the cover crop versus clean-weeding on the other Blocks should be interesting and valuable.

Treatment of Budwood with Fungicides.

A further advance in relation to the disinfection of budwood with fungicides and the clearing up of certain apparent discrepancies in the results obtained by the Rubber Research Scheme, Ceylon and this Institute are described in an article by R. P. N. Napper.

These further investigations demonstrate the different effects obtained on the viability of buds by similar treatments of two distinct types of budwood and indicate that it will be necessary, if the occa-

sion arises, to treat different types of budwood in a distinct manner, possibly both in respect of the type and the strength of the fungicide.

The paper also demonstrates the value of co-operation between the organisations concerned and other similar organisations in the East, which has developed very satisfactorily during the last few years.

GANODERMA PSEUDOFERREUM (FOMES PSEUDOFERREUS).

Our thanks are due to Mr. E. J. H. Corner, Assistant Director, Botanic Gardens, Singapore for his valuable contribution to the identity of the fungus causing Wet-root Rot of Rubber Trees.

It will be seen that the fungus causing "Wet-Root Rot" in Malaya, previously described by Plant Pathologists as *Fomes pseudoferreus* Wakef. is more correctly named under the combination *Ganoderma pseudoferreum* (Wakef.) Van O. et St. and the latter name should stand in the future.

THE MANURING OF RUBBER—III.

RESUMÉ OF PRESENT POSITION WITH ILLUSTRATIVE CASES BASED ON MALAYAN DATA.

BY

W. B. Haines and C. Falconer Flint.

Introduction.

In previous papers of this series, (1, 2,) the subject of manuring Hevea has been treated in its general aspects and the details of experimental technique for field work have been discussed. The present paper is the outcome of an endeavour to collate and interpret the miscellaneous mass of information, consisting of numerical data from experimental areas and other reports, which the Soils Division of the Institute has been able to assemble during the course of the last three years. Very much is still required by way of additional experience before systematic conclusions can be laid down and by way of stability of markets before economic values can be assessed, but enough knowledge has been gained at the present time to form a basis for a summary which will be useful for guidance and serve to clarify the position for further advance. It has been felt desirable to make this resumé of the position as complete as possible within itself, which will excuse some repetition of data or points of discussion that have already been published.

Chemical manuring for the improvement of crop products as regards both quality and quantity has, in many cases, advanced to a high degree of precision. Such specific manuring is the logical outcome of progress from the earlier days when knowledge was only adequate to achieve the encouragement of vegetative vigour. A great economic advance is represented by the ability to meet market demands by manuring for early maturity or for certain qualities in some special part of the plant. Such results must, of course, be viewed in proper relationship to the contributions toward improvement made along other lines such as plant breeding. This remark applies especially to the cultivation of Hevea, where the individual yield of trees varies so widely; the attainment of a uniform stand of high yielding trees by budding can increase the standard of yield per acre to a much greater extent than any improvements like manuring can do when applied to an ordinary mixed stand.

It is a matter of observation that the yield capacity of Hevea is not *closely* related to the size or vigour of the individual tree,

nor (what is more striking) to the apparent health of a stand and the ordinary fertility factors of a site. The amount of rubber removed from the tree also makes a comparatively small drain upon the total metabolic energy which is actively present. Again, one very important yield factor is the growth renewal of a particular portion of the tree, viz. the bark. All these considerations would support, on general grounds, the belief that Hevea might prove susceptible to manuring specifically for rubber yield, but there is as yet little or no information on this point and endeavours must first be applied to the task of relating the general facts of plant nutrition with the responses of Hevea. So many factors come into the question—age of trees, soil type and recent history of both trees and soil—that field experiments on a wide scale patiently conducted through several years can alone provide reliable answers. The scientist to-day has far sharper tools than in the past provided by improved methods of field experimentation, and by more uniform planting material (buddings), but our course must still be founded upon the century-old saying of J. B. Boussingault : "I would rather take the opinion of the plant than that of ten professors."

This paper, then, will attempt to deal only with the general manuring of Hevea, exploring the possibilities of yield improvements based upon the correction of poor nutrition in its effects on age of maturity, foliage and bark renewal. In all cases within our experience where trees of poor appearance have been successfully manured there have been obvious vegetative improvements first. One cannot make the converse statement so definitely, since cases of external improvement have not always shown increased rubber production. This may be partly due to a temporary diversion of physiological activity from latex secretion to general growth, in consequence of the change in nutritional balance. In so many cases yield increases have appeared after much delay, and our experience covers so short a period of time, that judgment cannot be definitely given on the side of failure but must still remain suspended. The economic aspect of the question of manuring, though always kept in mind, will not be specially discussed. From the data presented it is possible to make one's own estimate of returns based upon the particular postulates favoured as to normal profit on production, but while these postulates rest on such uncertain foundations as at present it is not practicable to attempt a formal presentation.

Manuring Possibilities.

It will be instructive to examine first of all the chief features presented by rubber estates which justify the recommendation

of manuring. Compared with other crops there is very little removed from the land when the latex is taken into the factory. In Table I the estimated amounts of the principal plant foods removed by various crops are compared. Evidently the heaviest crop of rubber will take from the soil only a fraction of that removed by most annual crops such as wheat. In passing it is interesting to notice that the increased yields expected from stands of the best budded clones might bring the nitrogen consumption up to comparable levels, though the mineral requirements would never be nearly equal.

TABLE I.

Weight in lbs. per acre of plant nutrients removed annually by crops.

	Latex giving 350 lbs. Rubber.	Potatoes.	Wheat.
Nitrogen ...	4	46	50
Potash ...	$\frac{1}{4}$	76	29
Phosphoric acid ...	$1\frac{1}{4}$	21	21

This comparison is not complete without an endeavour to estimate also the amount of these foods removed from the soil and stored in the tissue of the trees. Such an estimate can be based on an analysis by Bamber of the aerial parts of a tree. The estimate is approximate since the roots are not included and the single specimen tree must be assumed to be representative. This analysis indicates that a normal stand on 1 acre of land would contain, at 11 years old, about 10 cwts. of mineral food and about the same weight of nitrogen. The mineral matter includes 144 lbs. of potash and 81 lbs. of phosphoric acid, the remainder being mainly lime, magnesia and soda which are of less importance because less likely to be deficient in the majority of soils. Thus the 11 years of growth have corresponded, as far as concerns the principal plant foods absorbed and locked away, to 20 years of wheat as regards nitrogen or 4 or 5 years as regards potash and phosphate. This indicates at once the premier position which nitrogen is likely to take in relation to the manuring of rubber trees. Only a very small fraction of the total nitrogen content of a soil is available at any one period and the extent to which it becomes available is governed by soil texture, cultivation, soil temperature, rainfall and all the other factors determining the health and activity of the micro-organic population. It is also important to note that nitrogen may be lost without utilisation. Losses of nitrogen are associated with the leaf-fall. Thus the nitrogen content of the mature tree, plus the in-

significant amount removed in the latex, by no means represents the nitrogen consumption of the area by the trees since planting. While minerals like potash and phosphoric acid pass without loss into the soil from decayed leaves, much of the nitrogen may be lost in the gaseous form or as ammonia—particularly under certain conditions of decomposition. Much of the nitrogen which actually enters into the soil is nitrated, in which form, if not at once utilised, it may be leached away by drainage water.

Losses of nitrogen are also associated with the soil exposure that, in the absence of cover crops or shade trees, is inevitable until the rubber has made such growth as to shade the soil surface completely with its foliage. High soil temperatures greatly increase the rate at which nitrogen reserves are decomposed and converted to nitrate, which is not retained by the soil against leaching. Hence, except in the immediate neighbourhood of feeding roots, there is danger of complete loss in the drainage water. The roots of widely spaced young rubber trees in a new clearing explore only a small fraction of the total soil area, so that in those circumstances the presence of a subsidiary flora of any kind can act as a conserving agency both by absorption of spare food material and by shading the soil.

Most tropical soils have distinctly poor fertility reserves in comparison with the richness of the wheat soils of the world. This is the inevitable outcome of the high temperature and particularly the high rainfall under which tropical soils are formed, which allows of very small accumulation except in special circumstances such as swamp. The characteristics of an inland soil profile under virgin tropical forest are very deep weathering and heavy leaching, with a comparatively shallow surface horizon enriched by the forest litter. The forest cycle is one of fairly rapid vegetative growth, which arises more from the excessive heat and moisture than from inherent soil fertility. This growth brings up mineral foods from the lower depths of the soil and finally delivers them back to the soil surface combined in the decaying organic tissues of the plant detritus. In this surface layer nitrogen fixing organisms find a suitable habitat for maintaining the nitrogen element in the plant nutrition. Thus the poorest sites are found to be productive immediately after clearing jungle, but the natural cycle is broken and, under tropical conditions, the reserves associated with organic material in the surface layer are rapidly exhausted. This is in strong contrast to similar but deeper reserves accumulated in temperate regions under smaller rainfall, which are capable of lasting for very many years (e.g. prairie lands of Canada). The whole matter has been discussed in greater detail in a previous article, (3). Early cultivation in this country was based upon making full use of this temporary fertility for intensive crop

production and then moving on to fresh territory. But even the non-intensive cultivation represented by rubber planting has not been exempt from the exhaustion and deterioration following on clearing, mainly owing to the fixed policy of clean weeding, which has defeated even the natural tendency to revert to the forest cycle again. It cannot be too strongly emphasised that the chief adverse feature produced is the bacterial inactivity consequent on exposure, consolidation, and falling off of supply of organic material. The activity of soil organisms under forest is promoted by moisture, shade, open physical texture allowing aeration, and continual supply of decaying matter.

It is interesting to note that an acre of 11 years' old rubber was estimated to contain in its aerial parts nitrogen equivalent to that supplied by 2½ tons of sulphate of ammonia, while it may be said that an average soil under rubber in Malaya may contain about twice this amount in its top 6 inches, which is many years' supply after allowing for inevitable losses. This provokes the reflection that most soils should be able unaided to maintain healthy growth of Hevea provided they can be kept in a state of activity by proper management.

It is clear from these considerations how great an emphasis must be laid on a knowledge of the history of a site after the time of clearing. Injury by clean cultivation and erosion may be obvious on examination, but the reduction in available plant food due to previous cropping may be very great and this is not obvious to the eye although it will have very prolonged effects. From a recent statement by the Department of Agriculture, S.S. and F.M.S., it may be estimated that three successive crops of tapioca (covering a period of say 4 or 5 years) will remove from the soil as much nitrogen, phosphoric acid and potash as would be removed by rubber in 25, 10 and 20 years respectively. Sites which have been exhausted in this way when planted with rubber without special soil treatment give a stand of stunted, sparsely foliated, dry looking trees of low yielding capacity. With the poor shading and poor leaf fall no recovery of soil fertility takes place. Such stands of poor rubber are in rather sharp contrast with another poor type where the original planting conditions were relatively good and the trees have made good growth in the past. Falling off in the humus reserves of the soil then leads to nitrogen starvation and poor leaf development and bark renewal. In bad cases the trees suffer a reduction of crown by branch die-back, which is the natural response to the necessity of striking a balance of growth with the lowered fertility. Restoration of good conditions may be successfully undertaken (if neglect has not been too prolonged) by means of nitrogen fertilisers and the conservation of

humus by covers (including natural covers) and any necessary earthworks (bunds and silt pits).

Fertilisers are often applied for the purpose of forcing growth in young plants, particularly when it is required to bring them into line with a budding programme. If there is a real soil deficiency ready response may be obtained from a complete fertiliser, but two points tend to be overlooked. In the first place the young plant has its optimum rate of growth on a good soil and no excess in the nutritional factors is likely to increase the tempo of growth beyond that point. In the second place the limiting factor for growth may be moisture, and it is plain that food cannot be utilised without sufficient accompanying water. In such a case it is not efficacious to spend money on fertilisers when combating of drought is the outstanding requirement. The results on Block 6 at the Experiment Station of the Institute have made these points clear. The rubber on this Block is nearly three years old and receives various periodic fertiliser treatments. The soil is relatively poor and sandy but in spite of this there has been at no time any very marked advantage of growth on manured plots as compared with controls. At the same time severe checks to growth were often suffered in the earlier stages in dry weather, and it is to be inferred that watering during such periods would have shown better results than the fertilisers have done. In all cases where manuring is proposed it is important to inspect closely for any limiting factor, other than simple soil deficiency, which may be operating. In addition to drought this category includes poor drainage, hard pan and presence of salt or other toxic substances.

Types and Symptoms of Rubber Trees in Need of Manure.

The purpose of this paper is to deal practically and objectively with cases where the manuring of mature trees may be proposed as a likely means of increasing latex yield on stands now existing in Malaya. As already indicated rubber trees in need of such attention fall roughly into two groups, (i) well-grown trees at first entirely satisfactory as regards yield and appearance but later showing gradual deterioration and (ii) trees that have been stunted and abnormal in growth from planting and of low yield level since opening up. These are extreme cases; the groups are, of course, linked by imperceptible gradations.

The symptoms characterising the former group are a gradual fall of yield level, a slowing rate of bark renewal with an increasing sensitiveness to wounding, and the appearance of "die-back" in the upper twigs and branches with a thinning of leaves at the

top of the crown. Such deterioration occurs on any of the more fertile soils that have suffered from "wash" and clean weeding during the life of the existing trees. Often the original fertility has been reduced by other crops before planting Hevea, but deterioration also occurs on soils planted from virgin jungle, especially on sloping land. The indications are that nitrogen deficiency is responsible for the deterioration. It has already been shown with what ease the nitrogen reserves of the soil can be lost without being utilised for plant growth and, on soils of good depth and texture, with adequate supplies of other mineral food, nitrogen continues to be available for growth of the trees until the nitrogen reserves are almost entirely exhausted. There are cases in sharp distinction where nitrogen reserves exist but are for some reason not available so that trees may, throughout their development, suffer from nitrogen starvation.

The symptoms characterising the second group—trees stunted in growth since planting—are a small spreading habit suggesting a fruit tree in an orchard, small girth, hard thin bark and scanty foliage, with small and pale leaves. The differences in form are due to differences in shading; strong vigorous trees crowd one another and the branches go upward competing for light, while in starved trees with sparse leaves the branches grow outward and competition is mainly underground. From a distance the bark on these starved trees looks white, while the bark of healthy well-grown young mature trees is normally a reddish brown. This bark colour appears to be due to lichens living on its surface, their variety and vigour depending on the degree of shade under the trees and the ease with which they can obtain nitrogen and mineral food from the bark on which they grow. Such stunted trees may exhibit later further deterioration, but they are naturally slower and less sensitive to further adverse change than good trees since they have been more conservative in their vegetative undertakings and yield output, having adapted their physiological activity to scanty resources. Positive response to manuring may, however, be quite rapid.

It may be mentioned here that bark thickness and rate of renewal are sometimes observed to present anomalies which indicate that factors other than simple vegetative vigour must come into consideration, or that such vigour may be limited in definite directions. Thus trees of excellent crown and leaf development on flat (alluvial) land may show remarkably poor bark renewal when compared with similar plantings on other soil types. This is a hint from observation which will require research for its elucidation. The soil deficiency concerned is plainly not one of nitrogen.

Kinds of Fertilisers indicated.

It is now fully clear that nitrogen is the plant food of which a deficiency can most easily arise, since it can be lost from an area in many ways other than by direct removal in the crop. There are therefore practical and theoretical grounds for stating that, when good rubber trees suffer a late deterioration, the food deficiency is one of nitrogen only and other fertilisers need not be given. In the case of trees backward since planting on a poor soil, potash and phosphate may sometimes be needed (and perhaps other minerals also) although it would seem that in most cases a mature tree has a sufficiently extensive root system to be able to secure adequate supplies. The real opportunity to derive benefit from making up a mineral deficiency is during the early life of the plant and not later. Thus it is very noticeable that there have been many cases of good results from the use of phosphates with young rubber but very few with mature rubber. Hence, when manuring seems indicated, a straight nitrogen fertiliser should always be given precedence in trials on mature rubber. If potash or phosphates are required they will be needed in very much smaller doses since, relative to nitrogen requirements, only small amounts are taken up, and there is no serious possibility of their loss from the area once they have been applied.

Experimental Results.

Having outlined the problem of the manuring of rubber and indicated the requirements so far as they appear in the light of general agricultural knowledge and planting practice, we may proceed to present such generalisations and results as have been obtained by experimental investigation on various estates throughout Malaya. Trials in Malaya have been for the most part based on reports from experiments in Sumatra and Java in which the possibility of successful manuring with artificial fertilisers (in the economic sense) was most conclusively demonstrated. For the sake of completeness we propose, as an introduction, to discuss briefly outstanding cases from each of these countries. A statistical summary will then be presented of all cases in Malaya that have come in detail under the attention of the Institute, followed by a series of brief descriptions of fourteen of these cases selected for the instructive points which they present. As far as possible all relevant details of previous history are given, and for the purposes of comparison a "yield level" is always stated, this being a very approximate figure for the average yield of the untreated rubber in lbs. per acre per annum. In view of the wide differences obtaining—an acre may commonly yield anything between 200 lbs. and 900 lbs. per annum from a similar number of

trees—the expression of percentage increases would be ambiguous without such a statement.

Sumatra.

In Sumatra the classical investigation has been the well-known experiment by Grantham on the H.A.P.M. estates described in the *Archief v.d. Rubbercultuur* (4, 5, 6.) This is an experiment with nitrate of soda, sulphate of ammonia and other fertilisers on the "white" soil which is peculiar to the East Coast of Sumatra and which is exceptionally poor in available plant food. Experience has shown that rubber planted on this soil has arrested development and deteriorates very rapidly at about 5 or 6 years of age, when tapping begins. The experimental plots, planted in 1911, were first manured when the rubber was about 8 years old and showing a yield level of 250 lbs. of rubber per acre per annum. The experiment was laid down as a "chess-board" of $\frac{3}{4}$ acre plots, each treatment being replicated eight times, so that it is still the most accurate and most sensitive experiment on mature rubber for which published results are available. All the treatments in which regular dressings of nitrogenous fertilisers were given showed large and steady yield increases up to the 10th year. An annual dressing of 5 lbs. per tree of nitrate of soda gave a progressive increase each year which averaged 40 lbs. of dry rubber per acre per annum up to the 10th year: in the 10th year these plots yielded 764 lbs. per acre while the control plots gave only 361 lbs., i.e. the yield had been more than doubled. An alternate yearly dressing of 4 lbs. of sulphate of ammonia per tree gave an average yearly increase in yield of 31 lbs. of dry rubber per acre up to the 10th year: during the 10th year these plots yielded 671 lbs. per acre in comparison with the 361 lbs. from the control plots. The last year reported was the 11th (March '29 to Feb. '30) and was the first occasion on which there was a halt in the steady increases: this may be due to the abnormal (dry) weather for that year.

In connection with the manuring experiments by Grantham his experience with another soil type, important in its extent, on the H.A.P.M. estates is of great interest. This is a red volcanic soil which at first gave no response to fertilisers; the trees at this time, however, were quite satisfactory as regards growth and yield. It is now reported by Grantham (6) that after the trees on this soil reach 12-15 years of age, deterioration gradually sets in; the appearance suffers and yields fall. The maximum yield of nearly 650 lbs. of rubber per acre per annum appears to be reached in the 11th year.

An experimental chess-board similar to that employed on the "white" soil was laid down on this red volcanic soil to test on

small plots eight replications of each of several manurial treatments. The rubber was 15 years old with a yield level that had fallen to about 400 lbs. per acre per annum. Annual applications of 4 lbs. of sulphate of ammonia per tree gave for the first three years an annual average yield increase of 23 lbs. per acre. The increase during the 4th year (March 1929 to Feb. 1930) was somewhat less and corresponds to the halt shown by the "white" soil experiment in the same year, due doubtless also to abnormal weather.

It may be remarked at once that, although first attempts to reproduce these results in Malaya were often disappointing, yet yield increases of the same order have followed the application of nitrogenous fertilisers in the more successful cases. They have been exceeded in only one case within the experience of the writers (Case III), but this covered a much shorter period of time and to that extent must be considered less well established.

In 1926 Schmöle (7) reported a summary of results from upwards of 50 experiments on various estates along the East Coast of Sumatra. In every case the white soils had shown a yield response (as in the H.A.P.M. experiment), but results were meagre in other cases. About 40 per cent. of the total definitely reported no result, and the positive effects were only of the order of 10 per cent. on soils other than the white clay type. In estimating the significance of this report it must be remembered that most of the experiments had continued for too short a time for the judgment to be final.

Java.

From Java is reported a case of successful manuring of a somewhat different type. Rubber trees seven years of age and in fairly good condition were experimentally treated with phosphates and with nitrogen. After two years there was no response in yield though nitrogen had improved the appearance. At four years from the date of manuring all plots suffered with die-back, except those which had received nitrogen and tapping was stopped. Six years from the time of manuring, when tapping was tried again, the nitrogen plots yielded twice as much as the controls. Phosphate given alone was not effective, and it was not possible to judge whether its presence with nitrogen was important or not. In another experiment on 11 year old rubber in bad condition similar results were obtained from applications of sulphate of ammonia in alternate years. The distinctive features of both cases were that improvement was slow and attained under conditions of management which gave prominence to resting.

Van Heusden and Vollema (8) also report the effect of manuring on the growth of backward rubber trees in Java. The great interest of their results lies in the fact that potash and phosphate manuring combined with green manures gave good results, while the use of nitrogen fertiliser was not profitable.

Malayan Case Summaries.

In September, 1929, a classification was attempted of the various Malayan Experiments which had been reported. Most of them had at that time continued not more than two years, so that in view of the delayed effects which have been generally experienced the analysis errs on the pessimistic side. The judgment is based on yields in all cases. A summary of the results is given in Table II below.

TABLE II.

Result positive and "economic"	...	6 cases.
Result positive but uneconomic	...	13 „
Result a depression	...	4 „
No effect	...	5 „
Rejected as unsatisfactory for judgment		5 „
Total	...	33 „

A further series of about 100 cases were collected later by means of a questionnaire. The analysis of these has already been discussed (9) in the Annual Report of the Institute for 1930. There was a positive increase in yield in about 40 per cent. of the cases, a vegetative response without yield increase in 33 per cent. while only two cases reported a depression in yield. Twice as many experiments had been carried out on land previously cultivated as on land planted in rubber from jungle. As regards soil types the results were fairly evenly distributed, although it might be said that yield response showed the lowest proportion of cases on alluvial soils and the highest proportion on yellow soils.

The following detailed cases have been selected from a large number of returns as being sufficiently representative to give a fair idea of the whole and to cover all important features.

Case I. Kuala Selangor. An experiment with Urea on a heavy laterite clay soil, clean weeded, planted originally from virgin jungle and carrying 20 years-old rubber with a yield level

of 800 lbs. at the time of manuring. The experimental area is on a gentle slope, silt-pitted, and was divided into two plots of 15 acres each. $2\frac{1}{2}$ cwts. of Urea per acre were given in March 1928 to one plot with the result that its yield then showed a gradual advance over the control during the ensuing twelve months. The increase was not sufficiently lasting to be of value

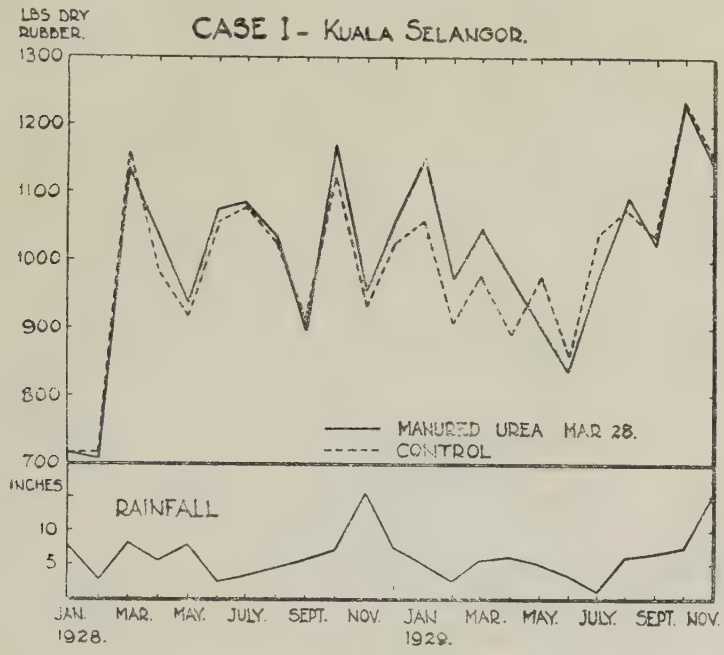

Fig. 1.

since the manured plot lost the advantage it had gained after about 15 months. The relevant data are shown graphically in Fig. 1. The curves illustrate the large variations in crop yield (due to outside influences, mainly rainfall) which are inevitable with rubber trees, but it may be remarked how closely parallel the variation in yields from contiguous plots may run under suitable conditions, e.g. if the plots are large enough, the area is uniform, and the supervision is adequate. This case illustrates the fact that present manuring methods do not give returns when applied to trees which are already yielding at a rate which may be considered high for the type of planting material.

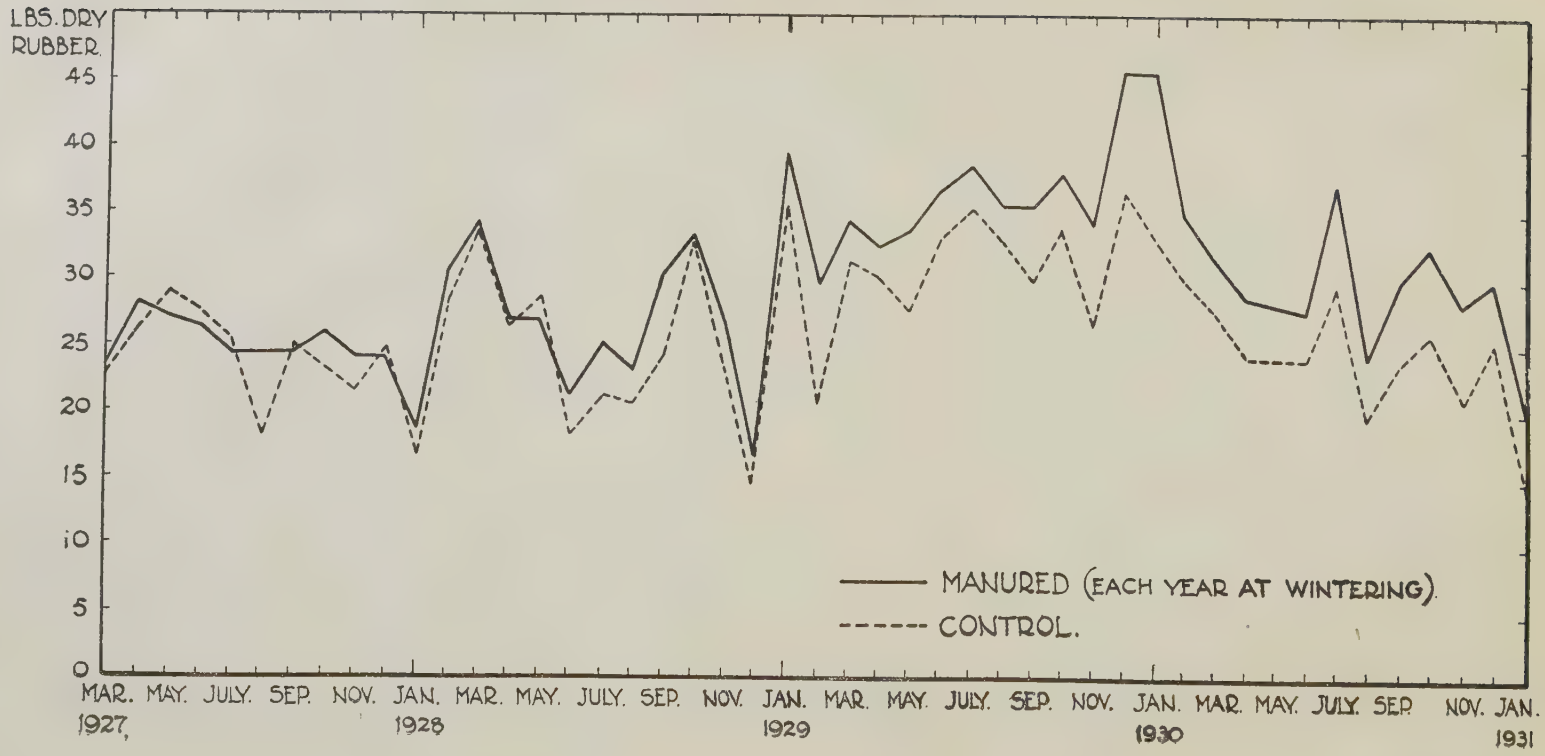
CASE II.- MALACCA.
LBS. DRY RUBBER.
45
40
35
30
25
20
15
10
5
0
MANURED (EACH YEAR AT WINTERING).
CONTROL.
MAR. MAY. JULY. SEP. NOV. JAN. MAR. MAY. JULY. SEP. NOV. JAN. MAR. MAY. JULY. SEP. NOV. JAN. MAR. MAY. JULY. SEP. NOV. JAN.
1927. 1928 1929 1930 1931

Fig. 2

Case II. Malacca. An experiment with sulphate of ammonia on a yellow-brown clay, showing scattered localities of white soil and small laterite outcrops. The area was replanted after a severe lallang grass fire, in which the original 5 years' old rubber was destroyed, and it has been clean weeded. No silt pitting was done until 10 years later so that heavy soil wash had occurred. The trees, planted 69 to the acre, were 14 years old when manured: 20 per cent. were permanently out of tapping and all showed pale scanty foliage, hard brittle bark, evident die-back and stunted growth. The yield level was then 300 lbs. The experimental area, on undulating land, was divided into 6 manured and 6 control plots, suitably disposed and each of about 5½ acres. Sulphate of ammonia was given in yearly doses of 4-5 lbs. per tree beginning in February, 1927. Figure 2 shows the average monthly yields per acre, after the first manuring, calculated from the totals for the manured and control plots. No improvement in appearance was noticed until after the second application, given in February, 1928, which corresponds to the time at which yield response also begins. The yearly means in lbs. of dry rubber per acre are shown in Table III.

TABLE III.

Year	Manured	Control	Percentage Increase
1927	298	292	2
1928	310	290	7
1929	425	373	14
1930 (calculated from a 10 months' basis)	347	281	23

Thus the increase has been steady, although so slow that it took 4 years to reach a value which, even in times of a normal market, could be regarded as economic. The fall in yield level in 1930 was doubtless due to the drought, the estate being so situated as to get a relatively low rainfall at any time. In this connection other experiments on the estate indicated that, even when other benefits were delayed, the manured plots showed in dry months much less tendency to fall in yield than did the controls.

Case III. South Kedah. An experiment with sulphate of ammonia on a sandy loam soil which had been kept clean weeded

for the previous 10 years and which had a short history of tapioca and padi cultivation before planting rubber. The trees had been interplanted with tapioca up to maturity and were 22 years old with a yield level of 400 lbs. per acre per annum when manuring was undertaken. The experimental area is slightly undulating and was divided into eight plots each of $1\frac{3}{4}$ acres; 4 of these remained as controls, 2 received 4 lbs. of sulphate of ammonia per tree in January, 1928, and 2 received the same amount spread over the year in quarterly doses. The greatest care was taken to eliminate the effects on the yield figures due to tapping. The records cover two periods of tapping with periods of rest intervening, and the monthly figures showed consistent and marked increases. The totals in lbs. of dry rubber for the two tapping periods are shown in Table IV.

TABLE IV.

Period.	Manured in 1 Application.	Control.	Increase per cent.	Manured in 4 Applications during 1928.	Control.	Increase per cent.
Manured Jan. 28 and rested.						
June 28 to March 29 inclusive.	1745	1382	26	1637	1406	16
Rested.						
Aug. 29 to March 30 inclusive.	1680	975	72	1662	978	70

Here we have an increase from a single dressing which reached 72 per cent. in the second year. Such a result must certainly be classed as "economic," and it is to be noted that it is associated with periods of resting. The preference is in favour of a single dose of fertiliser rather than smaller doses spread at intervals.

Case IV. Negri Sembilan. An experiment with sulphate of ammonia on a laterite soil of good quality somewhat resembling that in the Kajang district of Selangor, clean weeded from the time it was planted from virgin jungle. The rubber was 26 years old at the time of manuring, well grown but beginning to show signs of nitrogen deficiency, and the yield level had fallen to 250 lbs. Initially the experimental area was laid out as 2 control plots and 2 manured plots each of $2\frac{1}{2}$ acres; sulphate of ammonia was applied at the rate of 4 cwts. per acre in March, 1927. In February, 1928, a further application was made to half of each of

the two plots previously manured. The effects on yield were small, being nil in the first year, a slight depression during the second year and a slight increase in the third year. The experiment had then to be abandoned. The interesting feature was the increase in growth which was recorded, and it may well be suggested that this vegetative response is connected with the lack in yield response; the stimulus which was first absorbed in growth might be expected to show later in latex production. There was no growth shown in the girth figures for the two years 1927-1929 on the unmanured plots, but increases of 13 per cent. and 28 per cent. on the manured plots receiving one and two dressings respectively.

Case V. Kuala Selangor. An experiment with phosphates and nitrogen in various chemical forms on a coastal clay with a thin superficial layer of rather granular peat, kept clean-weeded from the time of planting from virgin jungle. The trees when manured were 13 years old, had always looked well and carried heavy foliage of good colour; the yield level was 250 to 300 lbs. The experimental area is dead flat and was laid out with 4½ acre plots, 6 being controls and 6 manured. The dressings were given in March 1927 and were repeated a year later. Careful records were kept for over 3 years and no significant differences were observed in yield, girth or appearance. The experiment was sensitive enough to have shown quite small effects had any been present. Such small effect as there was appeared to be a depression in yield. The feature which is difficult to explain in this case is the low yield level of the site, which has no obvious limiting factor. Several experiments on similar soil have given the same negative results, the land having been planted from virgin jungle in each case.

Case VI. Negri Sembilan. An experiment with sulphate of ammonia and superphosphate together and alone on a very shallow sandy loam soil overlying laterite gravel. The area was planted from lallang grass and belukar (secondary jungle) which almost certainly indicates previous cultivation, and it was always kept clean-weeded. When first manured, the rubber was 15 years old, showed a stunted growth, evident die-back, poor bark and foliage and a yield level of only 150 lbs. The site of the experiment lies along a regular slope and has been greatly subject to soil wash, though it is now silt-pitted: it was divided into 12 one acre plots, alternate plots being manured and an equal number left as controls. Dressings were first given in February, 1927, and the first results showed a response only where sulphate of ammonia was given, with no result from the superphosphate. Early in 1928 dressings were repeated in three of the manured plots and a year later a second application of sulphate of ammonia was

made to a plot that had its first application in 1927. All plots with nitrogen made steady gain and maintained it even to the third year after manuring. The two best plots were 61 per cent. ahead of the controls as regards yield in the first quarter of 1931, three years after the last application. At an early stage sulphate of ammonia showed the usual effect of greatly improving the colour and density of foliage and checking die-back.

Table V shows an analysis of results taking all the plots together that received nitrogen, with or without phosphate, and comparing with the totals for the control plots.

TABLE V.

	Ozs. per day.		Percentage Increase.
	Manured.	Control.	
Before Manuring ...	16.55	15.21	9
1st year (10 months) ...	18.50	15.58	19
2nd year (after 2nd dressing) ...	27.35	19.79	38
3rd year (new panel opened 4th month) ...	11.55	7.48	55

Girth and bark thickness figures were also taken at regular intervals and permit certain conclusions. For brevity, figures in Table VI are only given for the difference between the means of the 6 manured and 6 control plots for the various dates available: the comments made are from a consideration of figures for individual plots and groups of plots.

TABLE VI.

Bark Thickness in 1/32nds of an inch.

	Nov. '27	Dec. '27	June '28	Dec. '28	June '29	Dec. '29
Mean for manured plots ...	6.4	6.3	8.1	8.5	8.0	9.7
Mean for control plots ...	5.6	5.8	7.0	7.5	7.6	8.8
Differences ...	0.8	0.5	1.1	1.0	0.4	0.9

The figures for Nov. '27 and Dec. '29 are respectively 6 and 4 times the standard error of mean difference and merely taken alone are highly significant. A more detailed study of the figures from individual plots indicates that both sulphate of ammonia and superphosphate increased the rate of bark growth. With sulphate of ammonia the maximum effect from each dressing was reached quickly and the advantage was subsequently lost by the rate of growth falling to below that of the controls. A plausible explanation is that the greatly increased yields that were built up diverted the physiological energy of the trees. Superphosphate produced a greater effect, but more slowly; here again, after the maximum had been reached there was a gradual falling off but during the period of observation some considerable advantage was still maintained. Where this fertiliser was given with sulphate of ammonia, the initial advantage was intermediate in magnitude, developing at the same rate as with superphosphate only and showing the same steady falling off but with an advantage still retained at the end of the period. A later series of measurements, made at the time of writing (July, 1931) by an improved method, confirms the earlier results. The mean value of bark thickness for all manured plots was 12.7 per cent. better than for controls and this difference was definitely significant.

TABLE VII.

Girth measurements, (inches at 3 ft. from ground.)

	June '27	Dec. '27	June '28	Dec. '28	June '29	Dec. '29
Mean for manured plots ...	32.8	34.1	34.3	35.5	35.6	36.2
Mean for control plots ...	33.8	34.9	34.9	35.2	35.5	35.3
Difference ...	-1.0	-0.8	-0.6	+0.3	+0.1	+0.9

The significance of results in the girth measurements for individual dates is very low: the figures for June '27 and Dec. '29 are respectively only 1.7 and 1.6 times the standard error of mean difference. Considering figures for the series of dates it is evident that there is a significant drift in the positive direction indicating an increase in girth as a result of the manuring, but one would hardly be justified in stating that in June '27 the manured plots had

a significantly smaller mean girth than controls. From a more detailed study of the figures from individual plots, the conclusion seemed warranted that the sulphate of ammonia was responsible for the girth increase and that superphosphate made little or no contribution.

Case VII. River flats, South Kedah. (a) An experiment with sulphate of ammonia on a 2½ ft. deep peat soil over a blue-grey coastal clay. The peat contains a fair amount of quartz gravel, shows many still recognisable wood fragments, and is friable, elastic and spongy in the wet state. The area is quite level and is clean weeded and well drained. Before the planting of rubber it was for many years under sugarcane. At the time of manuring the rubber was 19 years old, the trees being of good girth and shape with good heads of quite normal foliage, so that the treatment did not produce visible improvement. The yield level was at about 200 lbs. of rubber per acre per annum and was in striking contrast to the appearance of the trees. The experimental area was divided into eight plots each of 2¼ acres arranged in a block; 4 of these plots were dressed with 4 lbs. of sulphate of ammonia per tree and alternate plots were kept as controls. Steps were taken to eliminate the tapping error, and both in this and the following experiment the greatest care was taken to make all measurements and records as reliable as possible. Three annual applications were given, the first in Janury, 1928. At the end of the years 1928, 1929 and 1930 the total rubber from the manured plots showed an increase over that from the control plots of 9.8 per cent., 16.1 per cent. and 22.9 per cent. respectively. Statistical examination of individual plot records showed even the first year's increase to be highly significant.

Measurements of bark thickness were also made in June, 1931, at levels on the panels representing a definite date (or age of renewal). For renewal since April, 1928, manured plots as a whole were 17 per cent. ahead of controls, and for renewal since January, 1930, they were 14 per cent. ahead. On statistical examination of individual plot returns the first of the above figures was found to be highly significant and the second reasonably so.

(b) An experiment with sulphate of ammonia, "Leunaphos" (containing nitrogen and phosphate) and "Urea BASF" on an area of hard clay soil. The top soil is dirty brown, and the sub soil is cream colour: skilful handling has rendered it fairly permeable to water since it contains quite a fair percentage of fine sand. The site, before planting with rubber, was under sugarcane for many years. The rubber was 20 years old at the time of manuring and showed a yield level of 250 lbs. of rubber per acre per annum.

The experimental area is flat, clean weeded and well drained and is divided into twelve plots, each of 2¼ acres, manured and

control plots being arranged alternately in two contiguous rows. A manured and control plot together formed a task. Of the six manured plots, two received "Leunaphos" (4.1 lbs. per tree), two received "Urea BASF" (2 lbs. per tree) and two received sulphate of ammonia (4 lbs. per tree), given in January, 1930. During the six months previous to manuring, total rubber from the control plots amounted to 1,930 lbs. and from the plots to be manured 1,934 lbs. By the end of 1930 the gains over controls (based on the figures for the last six months of the year) amounted to 28, 27 and 32 per cent. for "Urea BASF," "Leunaphos" and sulphate of ammonia respectively. Figure 3 shows graphs of monthly totals for the pairs of manured plots and the associated pairs of controls.

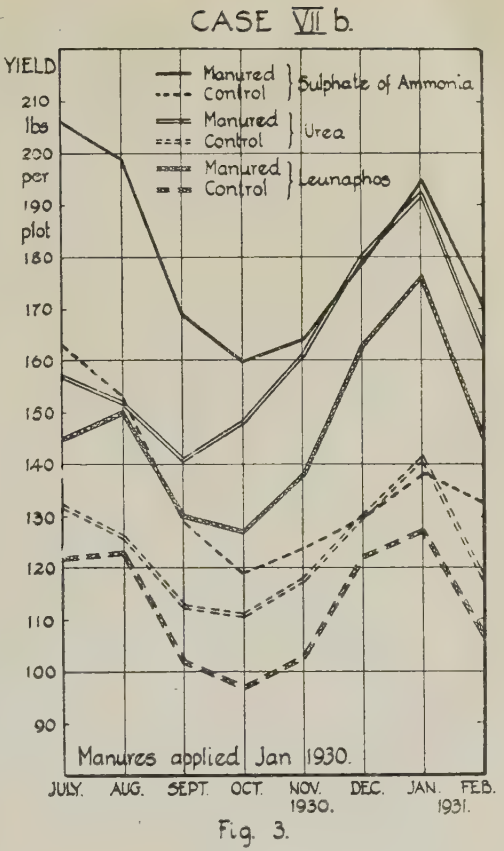

Fig. 3.

It must be explained that three tappers were employed on the experiment, each one tapping the two plots of similar treatment and their associated controls. Thus the variations in mean yield of these groups may be attributed to the variation in individual skill in tapping, and not to chance differences affecting the relevant comparisons for effect of manures. The large differences will illustrate the importance of covering the factor of "tapping skill" in the lay-out and conduct of experiments. This experiment is very encouraging as showing that quick and adequate response can be obtained even in 20 year old rubber.

Case VIII. South Johore. An experiment with sulphate of ammonia on a soil which varied from a white clay with sand and quartz fragments to a stiff red loam. The area was clean weeded to permit application of the manure. The area, before planting rubber, had been for some years under gambier, tapioca and other crops: the rubber was very backward and typical of that on a

thoroughly exhausted soil. At the time of manuring the trees varied in age from 12 to 16 years and showed a yield level of about 300 lbs. The experimental area varied from a dead flat to steep slopes (these last being properly contour drained) and was divided into 6 tasks, three of which were manured while the alternate tasks were kept as controls. Sulphate of ammonia was applied at the rate of 4 lbs. per tree early in 1927. Within a year die-back had been arrested and greatly improved foliage attained, while the manured plots at the end of 12 months showed a yield increase of about 80 per cent. over the controls which continued to yield at the original level.

On the same area, certain tasks were manured with cyanamide but showed little difference over the controls either in yield or appearance. In this case it was not found necessary to clean weed as the manure itself destroyed the cover.

Another experiment with sulphate of ammonia was laid down on well grown 11 year old rubber showing a much higher yield level. This showed no response during the first year and later results are not available.

Cases IX to XIV. Malacca District. These are a series of experiments all laid down on the same plan which was as follows:—

Plot A. Nitrogen. (Sulphate of ammonia).
„ B. Control.
„ C. Nitrogen. (Calcium cyanamide).
„ D. Control.
„ E. Potash and phosphate. (Concentrated superphosphate and muriate of potash).
„ F. Control.
„ G. Potash, phosphate and sulphate of ammonia.
„ H. Control.
„ J. Complete organic manure.
„ K. Control.
„ L. Potash, phosphate and nitrate of soda.
„ M. Control.
„ N. Nitrogen. (Nitrate of soda).
„ O. Control.

In all experiments, except Case XI, manured and control plots alternated in a single row of plots. Quantities were arranged so that nitrogen was applied at the rate of 70 lbs. per acre, phosphate at 40 lbs. and potash at 25 lbs. In Case XIII plots were of $1\frac{3}{4}$ acres; in other cases they were $2\frac{1}{2}$ acres. Control plot O was

omitted in Cases IX and X, and in Case XIV plots L, M, N and O were omitted.

Since in all cases there is no replication of the various treatments it is impossible to state rigidly definite conclusions as to the relative efficacy of the different fertilisers. However, when the graphs for the separate plots and their associated controls show a steady trend culminating in a striking divergence this may be taken as fair ground for positive conclusions. This difficulty should be borne in mind in considering the detailed accounts of the cases.

Case IX. The experiment was laid down on a heavy grey loam over a yellow clay sub-soil, with large outcrops of laterite. Before planting with rubber the area was for many years under gambier and tapioca. At the time of manuring the trees were 23 years old and showed a yield level of about 300 lbs. of rubber per acre per annum. Plots L and N were manured in July, 1928, and the others in November, 1927: second applications were given in November, 1929. Yield records are available for 3 years since the first manuring. Considering the general effect of the fertilisers the records show no significant differences over the period and indications are too small and unsteady to permit any conclusions as to the respective effects of the various fertilisers. This record is simply entered so that no unit in the series is omitted.

Case X. The experiment was laid down on a red loam soil with occasional laterite outcrops. Before planting with rubber, the area was for many years under gambier and tapioca. At the time of manuring the trees were 23 years old and showed a yield level of about 300 lbs. Fertilisers were given in January, 1928, to all except plots L and N which were treated in July, 1928. Second applications were given in November, 1929. Yield records are available for $2\frac{3}{4}$ years since the first manuring. The advantage of the mean of manured plots over the mean of controls was nil for the first year, 6 per cent. for the second year and 14 per cent. for the third year. The last figure appears to be significant on statistical examination of the data. It is not possible to draw any conclusions as to the individual effects of the various fertilisers.

The graph (Figure 4) shows the progress in time of the mean yields of manured and control plots respectively and the figures at various points indicate the significance of the mean difference in yield expressed in terms of the standard error of mean difference. Conventionally, a figure of 2 or more is held to be significant.

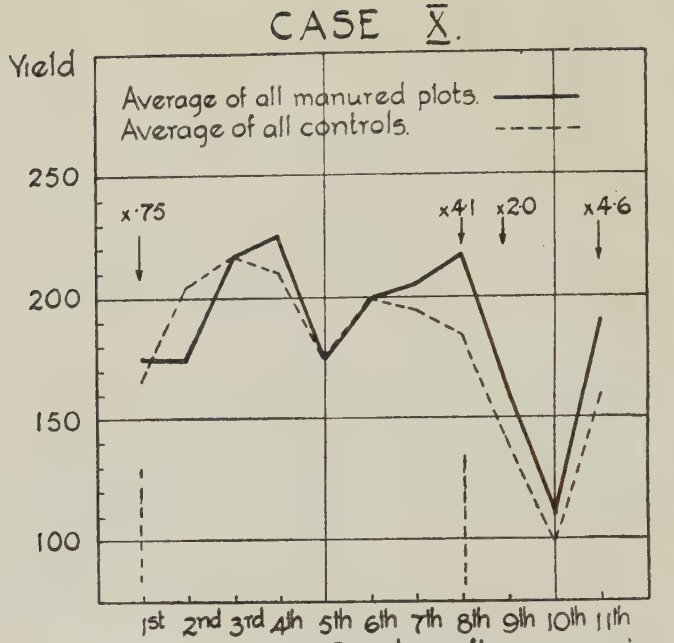

Fig. 4.

Case XI. This experiment was laid down on hilly ground, and the rather unusual course was taken of arranging in two contiguous rows one of which contained all the manured plots and the other all the controls. A hill rises in each of plots A and B and a sharp ridge runs along the junction between the remaining plots of the two rows, the crest lying over in the line of control plots. The area has been properly silt-pitted. There are two distinct soil types, Plots A, B, C and D lying on a grey fine-sand-with-clay and the remainder on a harsh orange-brown clay containing much sharp quartz grit. The history of any previous cultivation is not known, but the indications are that tapioca preceded the rather old belukar from which the area was cleared for planting.

All plots were manured in January, 1928, except L and N which were not treated until March: the rubber was at this time 16 years old and showed a yield level of 250 lbs. Second applications were given in August, 1929, and yield records are available for 3 months previous to manuring and for 3¼ years afterwards.

The advantage of the mean of manured plots over the mean of controls was 10 per cent. for the first year, 22 per cent. for the second year and 34 per cent. for the third year: the last two figures appear, from statistical examination of the data, to be significant.

CASE XI

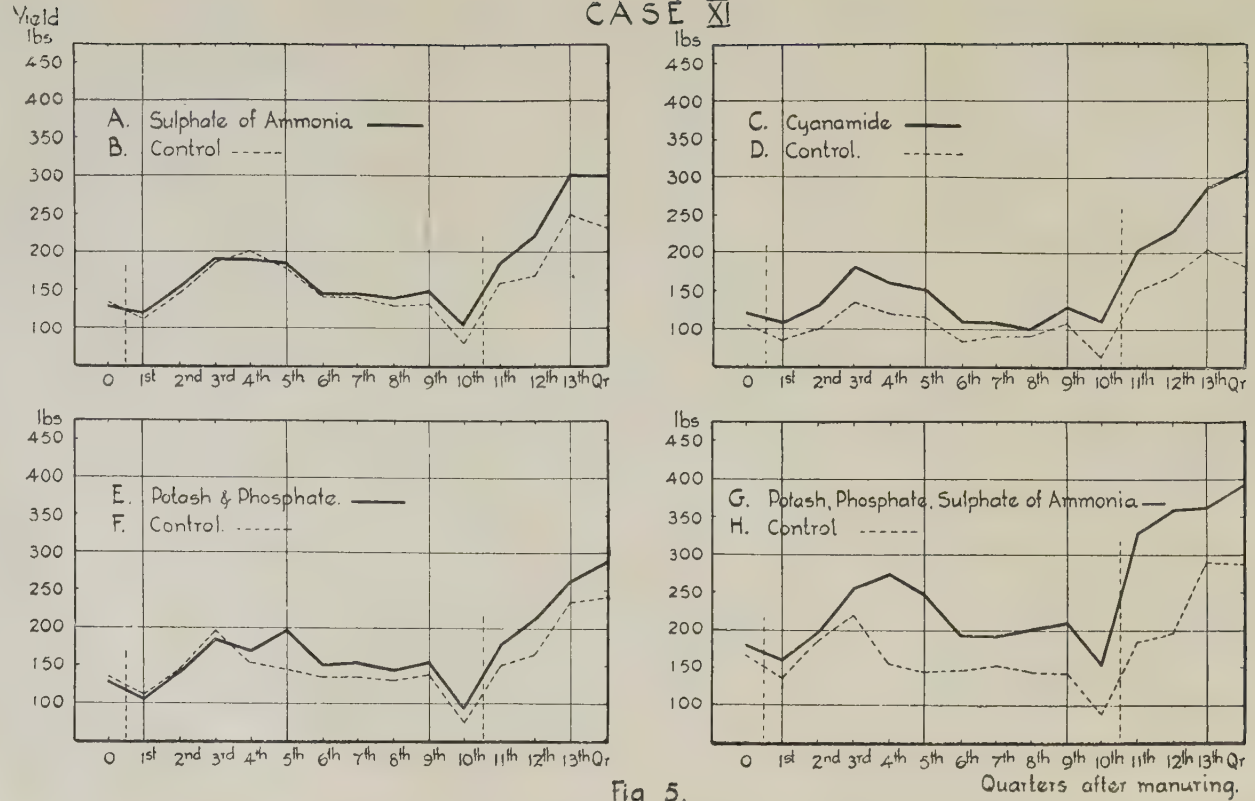
Yield
lbs
450
400
350
300
250
200
150
100
A. Sulphate of Ammonia
B. Control
C. Cyanamide
D. Control.
E. Potash & Phosphate.
F. Control.
G. Potash, Phosphate, Sulphate of Ammonia
H. Control
0 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th Qr
Quarters after manuring.

Fig 5.

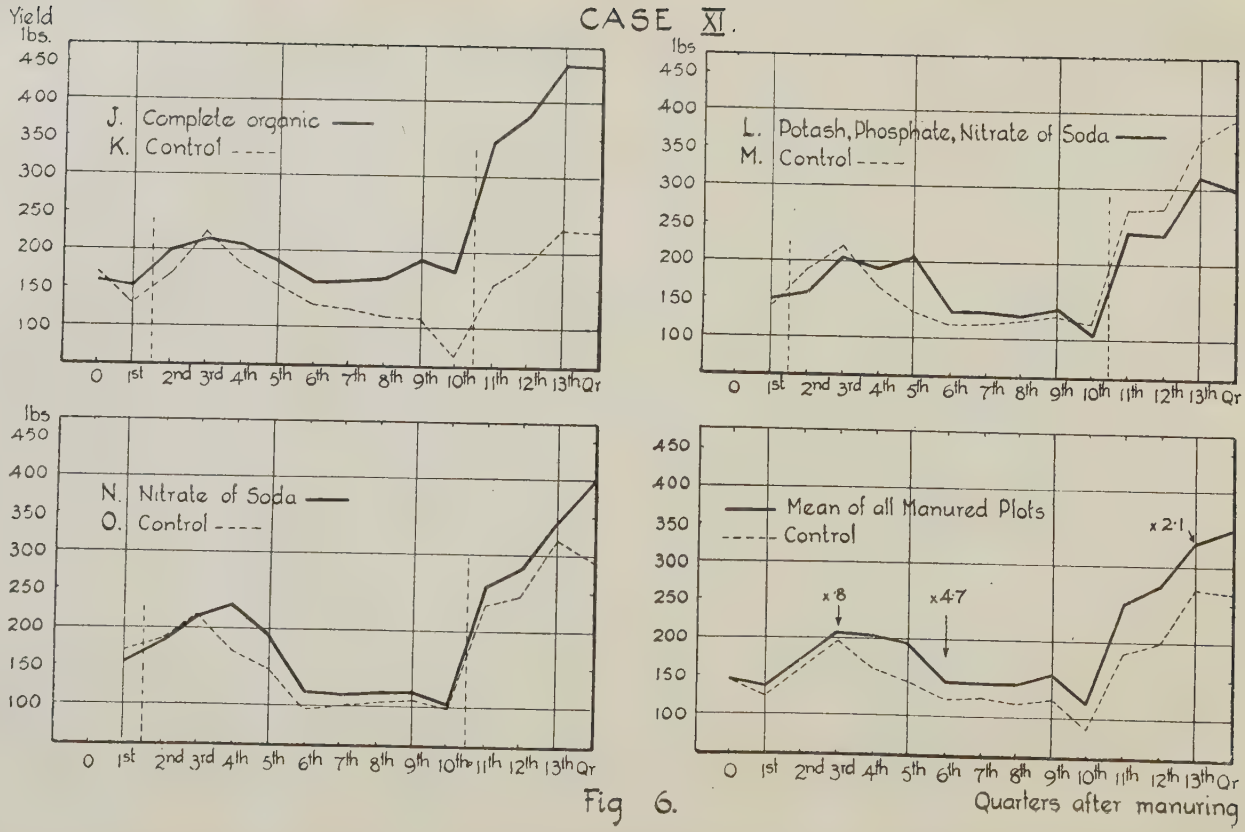
CASE XI.
Yield lbs.
J. Complete organic
K. Control
L. Potash, Phosphate, Nitrate of Soda
M. Control
N. Nitrate of Soda
O. Control
Mean of all Manured Plots
Control
x·8
x4·7
x2·1
0 1st 2nd 3rd 4th 5th 6th 7th 8th 9th 10th 11th 12th 13th Qr
Quarters after manuring

Fig 6.

A series of graphs is presented for this Case (Figs. 5 and 6) showing the progress in time of yields from each manured plot and its associated control. A graph of mean yields of manured and control plots respectively is also given, and the figures at various points express differences in mean yield of manured and control plots in terms of the standard error of mean difference.

These results are sufficiently definite to allow some comments on the individual effects of the various fertilisers. It should be recalled that the third year (1930) was exceptionally dry and caused a distinct set-back even in the results from white and red soil in the H.A.P.M. experiments. Further, the third year on this experiment shows a large increase in yield level of all plots caused by a change in tapping system from $\frac{1}{4}$ to $\frac{1}{2}$ cut. The May tapping holiday was a further complication.

Sulphate of ammonia shows an increase in yield developing from the end of the second year.

Cyanamide probably gave an increase in yield but judgment is difficult since the control appeared to yield more than the manured plot before the manuring.

Potash and phosphate gave an increase in yield beginning at the end of the first year.

Potash, phosphate and sulphate of ammonia gave a substantial increase beginning towards the end of the first year.

The organic manure gave a substantial increase beginning at the end of the first year and gradually accumulating.

Potash, phosphate and nitrate of soda gave a half-year of depression followed by an increase in yield during nine months and then a further depression which was apparently accentuated by the second application.

Nitrate of soda showed a positive effect starting about 6 months after the first application, fading out over the ensuing 18 months, and appearing again after the next application.

To summarise, we may say that the need shown is definitely for a complete fertiliser which should contain the nitrogen in the organic form or as sulphate of ammonia.

The whole experimental area was planted with Vigna but this did well only on the plot receiving potash and phosphate.

Case XII. The lay-out covered two distinct soil types, plots B, C and D falling on a deep soil of light sandy texture and light brown colour over a gravel sub-soil, while the remaining plots are on a grey fine-sand-with-clay of varying depth over a sub-soil of laterite which outcrops in places. The land was planted from old belukar with probably a previous history of tapioca cultivation, and the rubber was 22 years old with a yield level of 200 lbs. per acre per annum at the time of manuring. A hill

occurs, covering plots F, G, H and J with the summit in G and the area has been lightly silt-pitted. All plots were manured in February, 1928, except L and N which were dressed in May. A second application was given to all plots in August, 1929, and yield records are available for 3¼ years after the first manuring. The advantage of the mean of manured plots over the mean of controls was 8 per cent. for the first year, 43 per cent. for the second year and 23 per cent. for the third year: all three figures appear, from statistical examination of the data, to be significant.

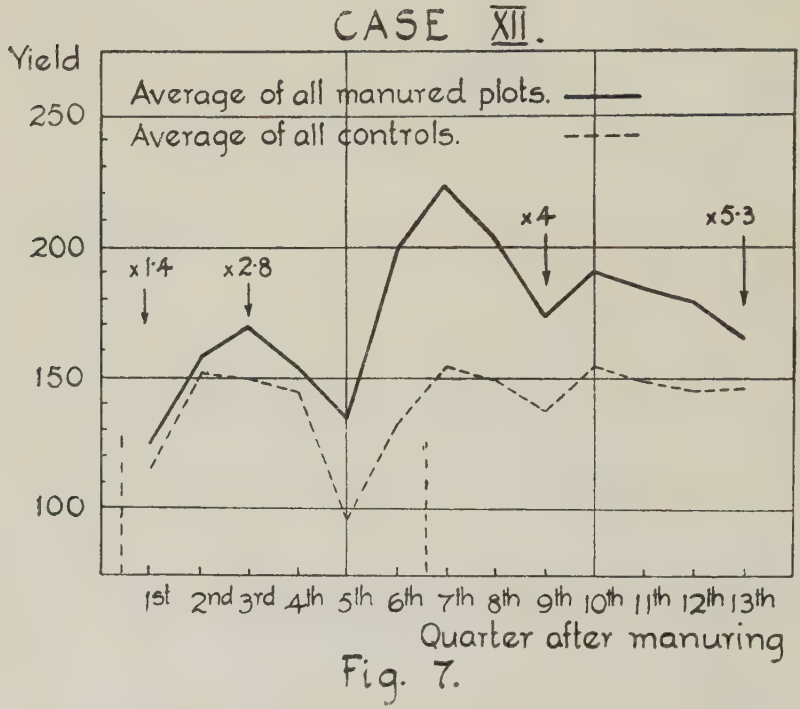

Fig. 7.

The graph (Fig. 7) shows the progress in time of the mean yields of manured and control plots respectively and the figures at various points indicate the mean difference in yield in terms of the standard error of mean difference. The slackening off of the yield increase during the third year is doubtless due, as has been suggested in other cases, to the abnormally dry weather experienced.

It is not possible to express very definite opinions as to the respective efficacy of the individual dressings in this case, as no records are available for yields previous to manuring and the trend of individual plot graphs is not sufficiently regular; but it is clear that the effect is by no means exhausted and that later results from this experiment will be of interest. It would appear

that the sulphate of ammonia gave the biggest response but that positive effects can also be attributed in varying degrees to all the manures applied, indicating that the need of the area was for a complete fertiliser.

Case XIII. The experiment was laid down on a poor, light-coloured sandy clay which had been for 27 years under tapioca before rubber was planted. During the first few years the trees were interplanted with tapioca. The rubber was 22 years old and showed a yield level of 250 lbs. per acre per annum at the time of manuring. Fertilisers were given in June, 1928, and September, 1929, and yield records are available for $2\frac{1}{4}$ years after the first manuring. Over this period the average yield for manured plots shows no significant advantage over that for controls and no definite conclusions can be drawn from the figures from individual plots as to the respective efficacy of the various fertilisers.

Case XIV. Details are similar to the preceding case as regards the soil and the rubber. The fertilisers were given once only, in December, 1927, and yield records are available for $2\frac{3}{4}$ years after the manuring. As in the previous case, no definite conclusions can be drawn as to the respective effects of the various fertilisers tried. The mean yields per quarter for manured and for control plots show that, with both sets of plots at about the same level during the second quarter, a yield increase developed, reached a maximum during the 4th quarter and disappeared by the seventh; but the position is complicated by a large increase during the first quarter which, as already mentioned, had disappeared three months later. This may possibly have been due to the fertilisers having been applied with a cultivation treatment that was not shared with the controls and the magnitude and duration of the effect supports this view. No information is available on this point and as no further records are likely to be forthcoming the experiment remains inconclusive.

The whole series of six similar experiments has thus shown interesting positive results in only half of the cases.

All the results so far presented are summarised in Table VIII.

Discussion.

Considering the proportion of cases giving uncertain results it is obviously not yet possible to undertake a manuring programme with the certainty of obtaining yield increases of a satisfactory order. Certain general rules however seem to emerge and, if these are respected, the odds in favour of success will be distinctly augmented.

In the first place, the yield level of the rubber should be low. Considering the average mixed population of rubber trees from

unselected stock that constitute the mature areas in Malaya, it has been unusual to find a notable yield increase from manuring on trees yielding 400 lbs. or more per acre per annum. Case III, therefore, is somewhat exceptional. On the other hand, it is common to obtain yield increases from trees yielding only 200 to 300 lbs. or less.

It is usual to find a yield response to manuring only on fairly old rubber. Response is obtained most readily from trees of good growth and appearance but poor yield. Trees with poor, thin foliage of bad colour show an immediate response as to appearance, but yield response may be delayed, for the bark has usually been affected and become thin, hard and dry. Since both foliage and bark must necessarily be in a healthy condition to make steady high latex production possible, and since bark is slower to respond than leaf, it is obvious that delay is to be expected. Within limits it may be said that the time taken to obtain yield response is proportional to the time during which the tree has been allowed to deteriorate.

Trees stunted from earliest growth on an inhospitable soil, although having hard bark and sparse foliage, often respond more rapidly to fertilisers than good trees that have deteriorated. It is plausible to consider that the stunted trees are hardier and more conservative in their metabolism and thus capable of swifter response to even a slight amelioration of soil conditions.

The necessity for patience in awaiting results and perseverance in applying fertilisers is amply illustrated by the case summaries and by the examples quoted from Sumatra. It is a fundamental error to abandon an experiment if results are not quickly forthcoming. Actually the majority of cases are only beginning to show signs of a yield increase after the lapse of a year, and sometimes even foliage improvement is by then barely perceptible. Should it prove impossible to repeat the dressing, or if the effects of a single application only are of interest, the experiment should not be lost sight of for at least seven years. This does not mean that yield records should be continuous, but that plot boundaries should be preserved and all relevant details properly recorded and filed and the area, though reabsorbed into the estate routine, should be treated uniformly as regards tapping, resting, and cultivation, so that at any time a period of test tapping over a few months can be made to reveal the existing state of affairs.

It should be emphasised that all estates wishing to undertake manuring should proceed cautiously along the line of careful experimentation though, as has already been observed, attention to the rules so far available will load the odds in favour of success. Experiments should be laid down under expert advice with attention to the provision of controls and of replication, and the utmost

accuracy employed in recording. In illustration, a case may be mentioned in which the latex yields were unaltered on manured plots, but the factory staff returned figures showing a notable increase in dry rubber content of latex. The natural elation of the management continued until proper tests discredited the factory method and demonstrated that dry rubber content also was unaltered.

While discussing the care necessary in conducting manuring trials, an example drawn from a very carefully conducted experiment may be quoted (Fig. 8). The graph shows the progress in time of yields from three control plots from the series, before and after adjacent plots were manured. Manured plots showed similar graphs, the differences due to manures being less than 10 per cent. and of doubtful significance. In a few months the yield level increased to four times its previous value, and this occurrence, though it really began before the manuring, so nearly coincided with it that the management would have been misled into thinking it was due to manuring had not proper controls been laid down. Incidentally the improvement shows how much scope there often is for the application of other methods than manuring, such as drainage and covers (natural or planted).

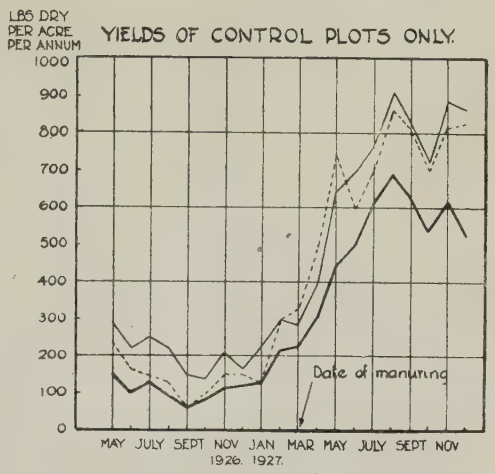

Fig. 8.

Little correlation can be discerned between the soil type and response to manuring, which shows that it is almost certainly only a secondary factor. It may be true to say that successful results are seldom obtained on friable red loam soils; but since it is equally true that such soils seldom carry poor yielding rubber this secondary factor is included in the primary factor of yield level and vegetative health in its relation to response to fertilisers. It has emerged that rubber of low yield level growing on certain coastal soils overlaid with peat does not respond to nitrogenous fertilisers. One is tempted to believe that low yields are here due to some direct inhibiting factor and not to a shortage of available nitrogen. In the cases studied, drainage appeared to be as adequate as the soil type permitted. It is interesting to note that these areas were planted from virgin jungle. On apparently

similar soils which had been for many years under sugarcane or other crops, rubber of similar yield level responded in a striking fashion to sulphate of ammonia (vide Case VII).

As might be expected, soils that have been under previous crops before rubber was planted show, in general, a very satisfactory response to manuring. Here again, however, yield level, affected by the soil exhaustion, is probably the primary factor. It is to be remarked that the best sites would be chosen for the earliest cultivation, so that, although the chemical values may be exhausted, the beneficial physical properties may to a large extent remain.

It is sufficiently obvious that the economic aspect of the manuring of rubber must consider the cost of the application as balanced by a number of extra pounds of rubber yielded by the area over a certain short period of time. Delayed effects, such as rate of bark renewal, or ultimate benefits from a prolongation of the yielding life or maintenance of yield level against diminution, are too difficult to assess in this early stage to permit inclusion in an estate budget. Thus a given dressing of manure is paid for by a definite number of pounds of extra rubber depending on the difference between the market price and the collection, factory, packing and transport charges of the particular estate. This quantity of rubber will represent a big percentage increase in crop when obtained from a low-yielding estate, but from a high yielding area it will appear as quite a small percentage increase.

On a given area of rubber, the greater the number of replications of similarly treated plots the smaller the percentage error of the experiment (or the degree of uncertainty) becomes, and consequently the smaller become the differences due to treatment that can with certainty be detected by it. Since on a high yielding area an economic yield increase may only be a small percentage increase of the total crop, it can be stated as a general rule that the higher the yield level of the area to be manured, the more elaborate will be the experiment required to demonstrate an economic advantage. Any extension of the time limit set to the covering of the fertiliser cost also reduces the percentage increase required and necessitates a greater elaboration of the experiment.

For the sake of argument one might assume a difference of 8 cents per lb. between the f.o.b. price of rubber and the factory and handling costs. Then the cost of a single normal application of sulphate of ammonia would require for balancing some 200 lbs. of extra rubber per acre, and even with a steady rate increase from manure amounting to 35 lbs. per acre per annum (about the order of the best increases established over a satisfactory period of time in Malaya and Sumatra) a period of three years would thus elapse before any profit was shown. Remembering that such rates of

increase have been obtained from biannual applications, it is very evident that at the present moment the expectation of a direct economic return from the general manuring of rubber is rather remote. However much market conditions may improve, the wisdom of attempting to nurse the old age of mediocre rubber will have to be seriously questioned as an alternative to replanting with buddings from high yielding clones. The effect of a dressing of sulphate of ammonia in arresting die-back and in giving a fine head of dense foliage is gratifying in the field but may prove nebulous in the office when an attempt is made to express it in the balance sheet.

Before closing the discussion it is necessary to emphasise again the contrast between the old and the new ideas of soil management under rubber. In so far as manuring is a remedy for mistakes of management it will pass in the course of time. It is possible that the application to rubber of nitrogenous fertilisers has by no means the future before it that is sometimes assumed. The future of "fertilising" rubber trees by soil applications is most likely to lie, for good soils, in specific manuring to force increased latex secretion and in the use of chemical stimulants with a selective action on desirable soil organisms. In the case of poor soils there would, in addition, be scope for materials to supplement such mineral deficiencies as may exist. Deficiencies of minerals such as phosphate and potash can only be made good by fertilising, but nitrogen supply can be kept up by fixation from the air through the action of bacteria (whether those in the root nodules of leguminous cover plants or other organisms living free in the soil itself) so long as conditions are suitable for their functioning.

So long as the application of nitrogenous fertilisers is attempted, the best returns are likely to be obtained from what is *potentially* the highest-yielding rubber. Ordinary mature rubber in Malaya, such as has formed the subject of the experiments discussed, is a mixed population averaging out at a low potential yielding capacity. Consequently, when by popular standards they are at a low yield level, they are likely to respond to manure, but, when yielding near to their full potential capacity, fertilisers can make little difference. With high yielding budded rubber, a high level by former standards might conceivably be so far below the full capacity of the trees that a striking response to manures might reasonably be expected.

The proportionate effect of nitrogen absorbed on latex produced might also be expected to be greater in buddings, for there is little or no general difference between high and low yielders, which argues that high yielders put a far greater fraction of their total metabolic energy into latex synthesis. On the same grounds, it is reasonable to suggest that high yielders would be more

sensitive to soil deficiencies as regards latex production than trees of low potential capacity.

It is of interest to remark in parenthesis that methods employed by the Botanical Division of the Rubber Research Institute for the selection of possible mother trees for budding are based not on the actual yield of individual trees but on a comparison of that yield with the mean yield level of the surrounding area.

It is thus likely that the application of fertilisers to high yielding areas of budded rubber will prove a far greater economic success than attempts upon the present mixed population of mature trees. In this connection the generalisation that satisfactory response is only obtained from areas of low yield level is definitely misleading unless the importance of the relation of potential to actual yield is properly understood.

It is quite probable that the improved methods of soil management on rubber estates now being introduced may make the natural sources of nitrogen amply sufficient for even the highest yielding rubber. It must be remembered that, although nitrogen requirements may be high, the activity of production is quite unbroken, which is in strong contrast to seasonal cropping where the time taken for green manuring or fallowing is of prime importance. In the case of wheat and other annual food crops, the entire soil surface is taken up by the plants and is annually disturbed and exposed by thorough cultivation. Modern methods of utilising the nitrogen-fixing power of soil organisms require that for long and regular periods, or in some cases, permanently, the whole soil surface shall be available for these activities and for the treatment that favours them. Hence they are likely to be of value only for permanent tree or bush crops which do not interfere with methods involving humus accumulation and decomposition under a natural cover or the growth and turning in of green manures over the whole soil surface. Modern intensive agriculture with annual food crops grudges the time spent in fallowing or growing catch crops for green manuring, and nitrogenous fertilisers, if cheap enough, are thus indispensable in any effort towards maximum productivity; but under a permanent crop like the rubber tree such considerations do not hold good.

There is every indication that the planting practice of the future will be along forestry lines in which the nitrogen supply of the soil is nicely regulated through the effect of the selective growth of natural covers on the volume and nature of vegetable debris reaching the soil and the light, heat and moisture conditions under which it decays. The pioneer work already done in this direction has been so successful that, however long the establishment may take, we may regard ourselves as at the point of a

new departure. Such methods require skilled direction but the minimum amount of labour and expenditure in execution.

Acknowledgments.

We desire to express our grateful appreciation of the careful efforts of Estate Managers and the willing co-operation of Agency Firms who have combined to supply the data discussed in this paper. We were entirely in the hands of the planting community with regard to the attainment of our ends, and record with great pleasure the unfailing cordiality with which we have been met and the painstaking care expended by helpers too numerous to mention.

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TABLE VIII.

Summary.

Case Number	No. of Control plots	No. of Manured plots.	Soil	Approx. area of each plot	Yield level at time of manuring in lbs. per acre per annum	Age of trees when manured	Soil under previous cultivation or not	Manure used	Period for which results are given	Observations considered	Result of Experiment
I	1	1	Red	15 acres	800	20 yrs.	No.	Urea	$1\frac{3}{4}$ yrs.	Yield	Temporary effect only
II	6	6	White	5 acres	300	14 yrs.	Yes	Sulphate of ammonia	4 yrs.	Yield	Steady yield increase
III	4	4	Sandy loam	$1\frac{3}{4}$ acres	400	22 yrs.	Yes	Sulphate of ammonia	$2\frac{1}{4}$ yrs.	Yield	Rapid yield increase
IV	2	4	Red	$2\frac{1}{2}$ acres	250	26 yrs.	No.	Sulphate of ammonia	3 yrs.	Yield & girth	Girth increase in 1st & 2nd yr. Small yield increase in 3rd year
V	6	6	Peat	$4\frac{1}{2}$ acres	250--300	13 yrs.	No.	Phosphates & nitrogen in various forms	3 yrs.	Yield & girth	No effect
VI	6	6	Sandy loam	1 acre	150	15 yrs.	Yes	Sulphate of ammonia and superphosphate	4 yrs.	Yield, girth and bark thickness	Steady yield increase and increased girth and bark renewal

TABLE VIII.

Summary.—(Contd.)

Case Number	No. of Control plots	No. of Manured plots	Soil	Approx. area of each plot	Yield level at time of manuring in lbs. per acre per annum	Age of trees when manured	Soil under previous cultivation or not	Manure used	Period for which results are given	Observations considered	Result of Experiment
VII (a)	4	4	Grey-white	2¼ acres	200	19 yrs.	Yes	Sulphate of ammonia	3 yrs.	Yield & bark thickness	Steady yield increase and increased rate of bark renewal
VII (b)	6	6	Grey-white	2¼ acres	250	20 yrs.	Yes	Nitrogen & phosphate in various forms	1 yr.	Yield	Good yield increase
VIII	3	3	White to red	1 task	300	12-16 yrs.	Yes	Sulphate of ammonia	1 yr.	Yield	Rapid yield increase
IX	6	7	Grey	2½ acres	300	23 yrs.	Yes	Nitrogen, minerals only & complete manures	3 yrs.	Yield	No effect
X	6	7	Red	2½ acres	300	23 yrs.	Yes	Nitrogen, minerals only & complete manures	2¾ yrs.	Yield	Yield increased during 2nd and 3rd year

TABLE VIII.

Summary.—(Contd.)

Case Number	No. of Control plots	No. of Manured plots	Soil	Approx. area of each plot	Yield level at time of manuring in lbs. per acre per annum	Age of trees when manured	Soil under previous cultivation or not	Manure used	Period for which results are given	Observations considered	Result of Experiment
XI	7	7	Grey to orange	2½ acres	250	16 yrs.	Probably	Nitrogen, minerals only, & complete manures	3¼ yrs.	Yield	Substantial increase during 2nd and 3rd years
XII	7	7	Brown to grey	2½ acres	200	22 yrs.	Probably	Nitrogen, minerals only, & complete manures	3¼ yrs.	Yield	Substantial increase during 2nd and 3rd years
XIII	7	7	Light coloured	1¾ acres	250	22 yrs.	Yes	Nitrogen, minerals only, & complete manures	2¼ yrs.	Yield	No effect
XIV	5	5	Light coloured	2½ acres	250	22 yrs.	Yes	Nitrogen, minerals only, & complete manures	2¾ yrs.	Yield	Possible initial increase. No effect during 3rd year

BLOCK 6.—MANURING EXPERIMENT, R.R.I. EXPERIMENT STATION.

THIRD REPORT.

Part I. Third Series of Measurements. January, 1931.

BY

C. Falconer Flint.

In the two reports (1) (2) already published on the Block 6 manurial experiment, the first described the lay-out of the experiment and presented a set of height measurements taken 11 months after planting, while the second considered in much greater detail a second series of height measurements taken 14 months after planting and interpreted the data by reference to a detailed rainfall chart covering the period of growth.

It is the purpose of this paper, as the first part of the third report, to present a series of girth measurements taken 2¼ years after planting. Details of the lay-out and the fertiliser applications are given in order to make this third report complete in itself. For the sake of brevity and clearness, the information is tabulated wherever possible.

The essential details of the experiment are summarised in Table I. The plots are situated on an area of flat sandy soil which has a dark well-humified colour to a considerable depth.

TABLE I.

Size and form ...	A 40 acre square.
Lay-out ...	Divided into 36 square plots, 6 plots being assigned to each of 6 treatments A, B, C, D, E and F.
Distribution of treatments ...	Indicated in Table IX, the top of the table being the north.
Planting distance ...	22 ft. × 22 ft.
Number of trees per plot ...	81, exclusive of guard rows.
Date of planting ...	October, 1928 (Stumps).

At the time of making the girth measurements (January 1931), soil samples were taken and submitted to the usual routine analysis for the purpose of record and to afford some basis of comparison for other workers on the same problems. The figures are given in Table II which is self explanatory. Two samples were taken from the same hole on each control plot, at 0-4 inches and 12-16 inches respectively. These were compounded to give one top-soil sample and one sub-soil sample for laboratory examination.

TABLE II.

Results of analysis of composite top-soil and sub-soil samples prepared from A plots.
(*All figures except pH values given as percentage of weight of oven-dry soil*).

	Top soil	Sub-soil
Sand ...	84	82
Silt ...	5	5
Clay ...	11	13
Loss on ignition ...	5.6	4.5
Carbon ...	1.57	
Nitrogen ...	0.082	
pH (electrometric, on soil suspension) ...	4.3	4.5
pH (colorimetric, on 1 :5 water extract) ...	5.4	
pH (colorimetric, on 10% KNO_3 1 :3 extract) ...	4.2	4.4
Potassium (in 1 :1 H.Cl extract) ...		0.007
Magnesium do. ...		0.016
Calcium do. ...		0.010
Phosphate do. ...		0.0018
Phosphate (in 1 :5 water extract)...	0.000018	
Colour (Ridgway's book of standards)—wet ...	Olive Brown.	Light Brownish olive.
Colour (Ridgway's book of standards)—dry ...	Light drab.	Isabella colour (light).

Table III gives particulars of the manurial applications up to the time of writing. Column headings indicate the nutritional programme assigned to each of the groups of 6 plots. Group A are controls. Table IV shews approximately the total amounts of plant foods given per tree.

TABLE III.

The manurial treatments and details of dates of application and amounts per tree.

Descriptive number.	Date of application.	Number of months after planting	B plots.	C plots.	D plots.	E plots.	F plots
			Organic.	Complete Inorganic.	Nitrogen only.	Nitrogen and Phosphate.	Phosphate and Potash.
1st.	October 1928.	At planting	4½ lbs. matured cow dung.	⅜ oz. Sulphate of potash. ⅜ oz. "20/20 Ammophos."	¾ oz. Ammonium sulphate.	½ oz. Ammonium sulphate. ¼ oz. Double superphosphate.	½ oz. Sulphate of potash. ¼ oz. Double superphosphate.
2nd.	July 1929.	9	6¾ lbs. matured cow dung.	2½ oz. "Nitrophoska"	1⅛ oz. nitrate of soda. 1⅛ oz. Ammonium sulphate.	2¼ oz. "20/20 Ammophos".	1⅛ oz. Sulphate of potash. 1⅛ oz. Double superphosphate.
3rd.	March 1930.	17	20 lbs. matured cow dung.	12 oz. Nitrophoska"	10 oz. Ammonium sulphate.	10 oz. "20/20 Ammophos".	4 oz. Sulphate of potash. 4 oz. Double superphosphate.
4th.	Septr. 1930.	23	← 3rd application repeated. →				
5th.	March 1931.	29	← 3rd application repeated. →				

TABLE IV.

Total ounces (approx.) of plant food applied per tree up to the end of the 4th manuring.

	B	C	D	E	F
Nitrogen ...	4.0	4.5	4.8	3.7	—
Phosphate (as $'PO_4$) ...	0.4	5.9	—	6.1	5.0
Potassium (as K') ...	1.4	5.0	—	—	3.9

The girth measurements were made at a height of 2 feet from the ground with a pair of wooden callipers designed like a large screw spanner, but with the lower jaw sliding freely on the shaft, graduated to read directly inches of girth in terms of the diameter to which it is applied.

Table V gives details of the number of trees omitted from measurement, for reasons directly due to root disease. Since in the majority of cases less than the full number of 81 trees could be measured in a plot, totals for each plot were corrected on a basis proportional to this figure and are here quoted only after correction :—

TABLE V.

Shewing details of numbers of trees measured; guard rows were not measured.

Theoretical number of trees to be measured ...	2,916
Number actually measured ...	2,831
Too small for measurement (recent supplies) ...	63
Trees missing (soil treated for disease and awaiting supplies) ...	16
Trees dying of root disease ...	4
Trees dead due to root disease ...	2

Table VI shews the corrected girth totals for each of the six different treatments including controls. Table VII gives these same figures expressed as a percentage of the mean, and indicates the extent of the difference between respective manurial treatments and control. When supplemented by the figure for standard error, obtained as will presently be indicated, Table VII expresses the result of the experiment represented by this series of measurements.

TABLE VI.

Girth totals for groups of 6 plots, arranged according to treatment.

A.	B.	C.	D.	E.	F.	Grand total.
2,892.	3,216.	2,983.	3,027.	2,846.	2,885.	27,849.

Mean, per group of 6 plots, 2,974.8

TABLE VII.

Girth totals per group of 6 plots, arranged according to treatments and expressed as a percentage of the mean figure per group of 6. The lower row of figures shews deviations from the figure for the A control plots :—

A. Control.	B. Organic.	C. Complete inorganic.	D. N only	E. N & P.	F. P & K.
97.2	108.1	100.3	101.7	95.7	97.0
	+10.9	+3.1	+4.5	−1.5	−0.2

Standard error 1.96 per cent.

It will be seen that only the treatment with cow dung and that with inorganic nitrogen without phosphate or potassium give a significant girth increase, when the criterion is the conventional test of differing from the control figure by more than twice the standard error.

Table VIII gives the frequency data.

TABLE VIII.

Frequency data for the 2,831 trees measured.

Girth classes, in inches.	Number of Trees.
0 — 0.5	2
0.6 — 1.1	35
1.2 — 1.7	46
1.8 — 2.3	38
2.4 — 2.9	42
3.0 — 3.5	62
3.6 — 4.1	122
4.2 — 4.7	209
4.8 — 5.3	267
5.4 — 5.9	361
6.0 — 6.5	408
6.6 — 7.1	446
7.2 — 7.7	314
7.8 — 8.3	184
8.4 — 8.9	124
9.0 — 9.5	88
9.6 — 10.1	32
10.2 — 10.7	29
10.8 — 11.3	14
11.4 — 11.9	5
12.0 — 12.5	2
12.6 — 13.1	1

The frequency curve is remarkably smooth and shews little evidence of a mixed population. Its peak is sharp but slightly bent towards the region of highest readings giving a gentle concavity on this side above what should be the point of maximum inflection. A slight hump distorts the curve in its first few points, as can be seen from the table, but although this indicates the presence of trees which do not belong to the normal population, their effect on the final result would be so small that their elimination from the experiment was not attempted. This hump is the only feature that suggests the second or "stagnant" class that was of such prominence in Haines's first two series of measurements, but probably represents the biggest of the trees planted as supplies to replace deaths from root disease.

Examination of the frequency data was held to justify an analysis of variance for the application of the tests of significance described by R. A. Fisher (3).

TABLE IX.

Deviations of girth totals for plots from a working mean of 500, arranged according to position in the field.

							Totals.
	E −22	A +26	B +49	F −17	D −24	C + 6	+ 18
	F −34	B +54	D + 8	E −42	C −62	A −25	−101
	D +14	E −24	A −51	C −56	F −51	B + 5	−163
	C +68	F +30	E −41	A −21	B +24	D −40	+ 20
	A + 5	D +21	C −12	B +37	E −27	F −46	− 22
	B +47	C +39	F + 3	D +48	A −42	E + 2	+ 97
Totals.	+78	+146	−44	−51	−182	−98	−151

Table IX is, in effect, a diagram of the experimental lay-out (the north being at the top of the table) and gives deviations of the girth totals for each plot from a working mean of 500. In Table X the figures have been employed to give the analysis of variance, from which follows the test of the significance of the experiment and the calculation of the standard error used in Table VII.

TABLE X.

Shewing analysis of variance, test of significance and calculation of standard error.

	Degrees of freedom.	Sum of squares.	Mean squares.	$\frac{1}{2}\log_e$ (mean square.)
Rows ...	5	11,810.8	2,362.16	1.5811
Columns ...	5	7,264.4	1,452.88	1.3381
Treatments ...	5	15,413.1	3,082.62	1.7143
Error ...	20	11,301.4	565.07	.8659
Total ...	35	45,789.7		

Comparing treatment with error, the Z value is 0.8484 while the 1 per cent. point is 0.7058. The experiment is therefore significant.

The Standard error (total of 6 plots) is the square root of $565.07 \times 6 = 58.22$; or 1.96 per cent. of the mean girth per group of 6 plots.

Discussion of Results.

From a consideration of Table VII, the following points emerge :—

(1) A total of 51 lbs. of matured cow dung (B plots) applied in increasing quantities at four specified times has given a 10.9 per cent. girth increase which is statistically highly significant. The dung was estimated to contain 4 ozs. nitrogen, 0.4 ozs., phosphate and 1.4 ozs. of potassium.

(2) Application of 4.8 ozs. of nitrogen in inorganic form without phosphate or potassium (D plots) gave only a 4.5 per cent. increase, which is also statistically significant.

(3) A mixed inorganic fertiliser (C plots), similarly applied and totalling a similar weight of nitrogen accompanied by comparable amounts of phosphate and potassium, gave only a 3.1 per cent increase, which is hardly significant.

(4) Similar applications (E plots) of rather less nitrogen and nearly twice as much phosphate show a depression in rate of girth increase, but this is not significant.

(5) The application of phosphate and potassium (F plots) was without effect.

Considering first, without reference to statistical significance, the groups receiving inorganic fertilisers, viz. C, D, E and F, nitrogen would seem to be the chief manurial requirement. The presence of a relatively large amount of phosphate seems to more than cancel the effect of a nitrogen dressing, though the addition of potash would appear to balance the depressing effect of the phosphate, both when nitrogen was added and when it was omitted. Since nitrogen and potassium were not given together in the absence of phosphate, this point cannot be checked nor can the existence of a potash deficiency be adequately tested.

As the B plots, which received nitrogen and more than three times as much potassium as phosphate, gave more than twice the increase furnished by a similar weight of inorganic nitrogen only, this might be considered as evidence in favour of the compensation of phosphate depression by potassium and the existence of a positive

potassium response. It would, however, be more generally held that since the elements were applied in a bulky organic manure rich in bacterial life, the argument is invalidated.

In connection with the apparent depressing effect of phosphate on the girth increase of the young rubber, it may be remarked that reference has been made by this Division on several occasions to a depression of yield of mature rubber following phosphate dressings There is evidence (4) that water soluble phosphates only are implicated, and in this experiment phosphates were all given in the water soluble form.

The figure 0.18 parts per million of phosphate in the soil water extract (Table II) is a very usual one on Malayan rubber soils and, taken in conjunction with the sandy nature of the soil, indicates an adequate and sufficiently available supply.

The term "acid soluble potassium" conveys no evidence of availability.

According to results and observations discussed by Salter (5) and previous workers, the wide carbon-nitrogen ratio (19 :1) suggests that the nitrogen reserves, which are low in any case, would not be easily available for plant growth, and that the soil would therefore show a marked response to nitrogen dressings.

The cow dung, apart from its own nitrogen content liberated by micro-organic decomposition, should also be considered as an application of useful bacteria in a medium on which they could continue to thrive when it is dispersed in the surface soil. Thus, as the introduction of many points of persistent infection, an application of farm-yard manure might be expected greatly to assist the decomposition of nitrogen reserves in a soil in which a sluggish micro-organic population made availability low. On this soil type the superior efficacy of cow dung over inorganic nitrogenous fertilisers in promoting the girth increase of young rubber is therefore attributed to a dual effect—its nitrogen content *per se,* and its microbiological effect as a bacterial culture in rendering more easily available the soil nitrogen reserves.

Girth has an important economic aspect in determining the age at which an area can be brought into tapping. It must be emphasized that the effects to date of the treatments are of such low magnitude as to be without economic value; but if the trees maintained the same acceleration of growth as in the B plots, they could probably be brought into tapping a year earlier than control plots as a result of the manuring. Two factors have, however, to be considered. Firstly, the difficulty of securing large supplies of farm-yard manure (a difficulty which might be met from the preparation of artificial farm-yard manure from cover crops); secondly, rubber trees probably have a

maximum rate of growth which may be attained but which cannot be exceeded by supplying fertility deficiencies. The second factor tends to destroy any promise of a continued acceleration of girth increase on Block 6, for there is evidence that in the presence of other limiting factors the maximum rate of growth has already been nearly achieved.

Part II. Fourth Series of Measurements. May, 1931.

BY

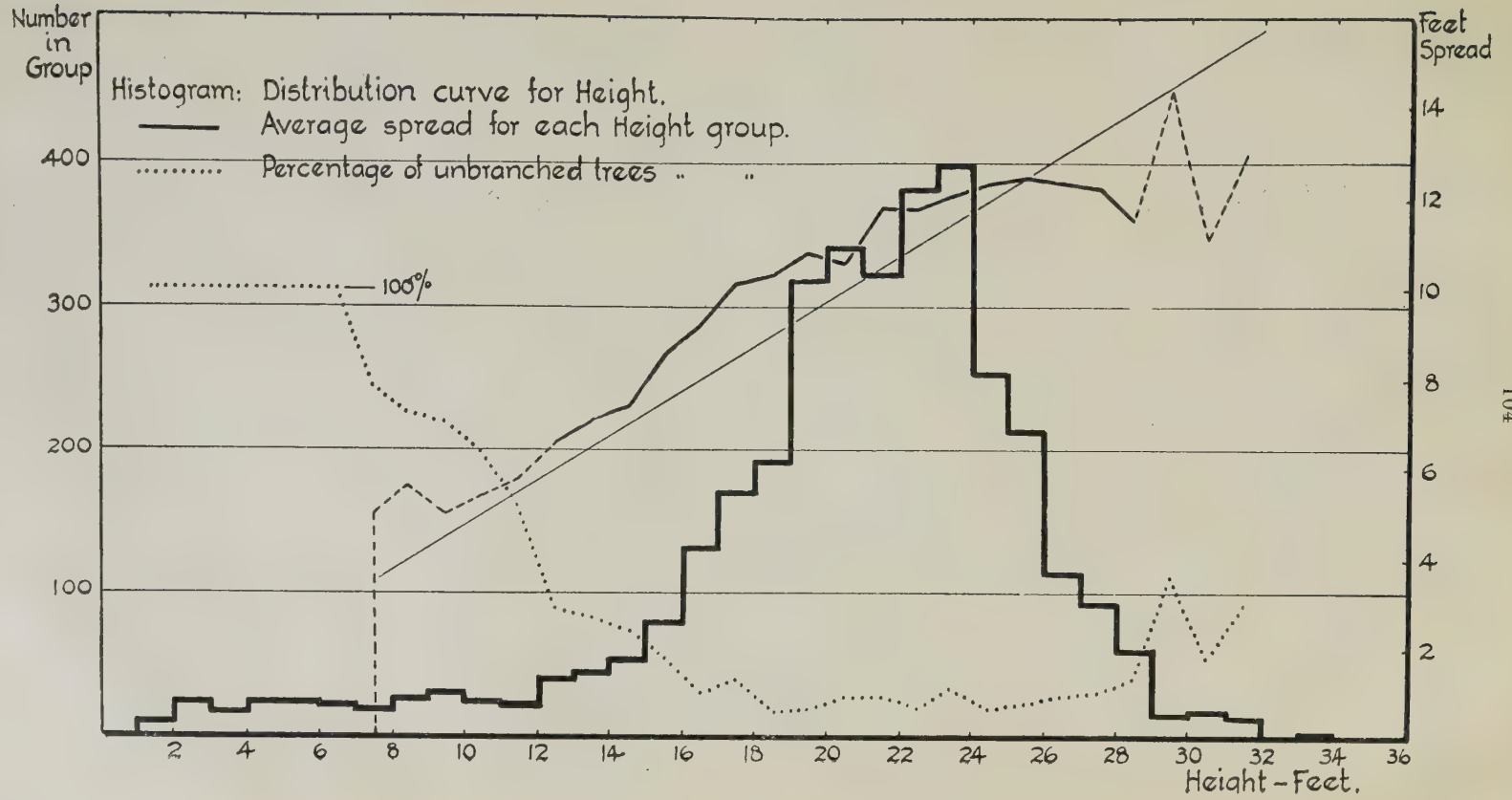
W. B. Haines.

The fourth series of measurements on Block 6 were carried out when the trees were just over two and a half years' old from the time of planting. Direct measurements of height with a bamboo scale were made and, owing to the change in form which branching had produced, an additional measurement of spread was made by means of a cross piece attached to the vertical scale. Readings were made as before to the nearest three inches.

It was found convenient to use field glasses in making the records, as this allowed the observer to stand some distance from the tree and so reduce the elevation of the line of sight to comfortable proportions.

The frequency curve for the height records was first examined, and the result is shewn in the diagram as a histogram for groups of 1 foot interval. The main part of the curve is approximately normal in form, although still bi-modal as in the case of the height measurements taken a year earlier, and it trails off at its lower end into groups of very small trees. These can be definitely eliminated as a special class of "casualties", being mainly supplies that have replaced trees lost by disease, lightning or other causes. All entries of height of 12 feet or under were considered to be in this special class and were rejected in the calculations for the normal population which are described later.

Measurements a year earlier had shewn two groups of trees with modes (i.e. most frequent height) at about 3 feet and 8 feet respectively; this separation was attributed to a "barrier" to growth produced by periods of drought acting on trees below a critical size, and so retarding a group small in size separated from the vigorously growing group. It is apparent that nearly all trees have now passed this critical point and are growing vigorously. The separation can still be noticed, however, in the two modal values at 20 feet and 23 feet, but the difference is obviously vanishing, shewing the capacity of the delayed trees to catch up to the others that were favoured early. A large proportion of the trees must have made quite ten times as


Number in Group
Feet Spread
Histogram: Distribution curve for Height.
Average spread for each Height group.
Percentage of unbranched trees " "
100%
400
300
200
100
14
12
10
8
6
4
2
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36
Height - Feet.

much growth (in height alone) during the last year as they made during the first.

Before proceeding further it will be necessary to decide upon some convention as to the method of combination of the readings for spread and height in order to give the best index for total growth. Hevea trees of mixed origin have a very varied manner of branching. At the stage now under discussion the trees have forms varying from a tall stem without branching (so called "bottle-brush" shape) to a dense dome of leaves formed by many branches radiating in all directions. Discrimination as to the number of branches was impossible in view of the large number of entries to be dealt with; and it was thought desirable to adhere to the conception of branch length, which would still represent "linear" growth in a fashion comparable with the earlier measurements of height, rather than to reduce spread to an expression of area (or volume). It was decided also, in the absence of more detailed knowledge, that it would be fair to give about equal weight to the two entries for height and for spread in combining them to a single figure. On examination of a few of the figures it was found that, on an average, twice the spread was nearly equal to the height; so the conception of an average tree was evolved having the form of a single vertical shoot and four equal branches. The total (linear) growth could then be expressed as height plus twice the spread of the tree, and this convention was adopted for combining the double entries and arriving at total growth.

The validity of this convention derives some support from an examination of the average spread of trees of the same height, using the groups which had been formed for the height frequency curve. The result of these calculations is shewn on the diagram as a curve in full line. The straight line shews the locus of those values of spread which, multiplied by two, would exactly equal the height. The calculated averages are in the main a little in excess, but follow the assumed relationship fairly well. The curve falls off toward the higher values, which expresses the fact that among the taller trees there has been some tendency to make height at the expense of spread, probably associated with late branching.

Unbranched trees, which had no entry for spread, were separately accounted for, and the dotted curve in the diagram shews the percentage which they formed in each group. Up to 7 feet height they form the whole of the group, but entries for spread begin at that point and steadily reduce the percentage of unbranched trees until at a height of 16 feet an almost constant value is reached. This value represents the proportion of trees of the distinct bottle-brush habit. It remains constant through the more numerous groups, but naturally increases again in the highest groups. For the average tree we may conclude that branching develops during the stage between

7 and 16 feet in height. Hence nearly the whole normal stand has entered the branched stage, since trees under 12 feet have been excluded from the normal population.

The "casualty" class, containing trees of 12 feet and under (and including blanks also), forms 9.5 per cent. of the total. The incidence is related to location in the field but not to the treatments which the plots have received. This is indicated in Table XI in which the total casualties have been taken in three different ways, viz. for groups of six plots according to treatment, and according to position in rows taken in two directions at right angles. The latter are distinguished as "rows" and "columns" as derived when the figures have been set out in a tabular plan of the plots.

TABLE XI.

Incidence of "Casualty" Group.

	Treatments.	*Rows.*	*Columns.*
A	... 46	36	61
B	... 41	47	35
C	... 49	47	52
D	... 47	45	35
E	... 47	46	52
F	... 48	57	43

The first row of plots with the low figure 36 is bounded by a road, while the column with the high figure 61 forms the extreme edge of the Block next the jungle. Both are in the line of movements of labour going from one part of the estate to another, and the reflection is suggested whether some difference may have been caused by the traffic going through the rubber in one case and not in the other. It is not likely that root disease from the jungle edge could be blamed at this stage.

The Pathological Division survey for *Fomes lignosus*, made at about the same time as the measurements under discussion, gave a figure of 6.0 per cent. for the incidence of this disease, including all trees shewing external mycelium as well as trees attacked or killed.

Table XII shews the values of mean growth for the plots calculated in the manner already described. The figures are expressed in feet; the first figure is the average height for the plot, the second is twice the average spread, while the third, in heavy type, is the sum of these two as used for the analysis of total growth.

Where trees are unbranched this indicates a definite habit rather than mere poor development, and it gives too little weight to their value for total growth if the spread entry is treated as zero. A very low conventional value for spread was therefore assumed and used in the calculations for these cases.

TABLE XII.

E	A	B	F	D	C
21.69	22.90	22.74	20.81	21.28	21.67
22.07	21.94	23.68	18.94	19.09	20.32
43.76	**44.84**	**46.42**	**39.75**	**40.37**	**41.99**
F	B	D	E	C	A
21.43	22.88	21.55	20.72	20.59	20.61
20.10	22.88	22.22	20.70	18.93	18.41
41.53	**45.76**	**43.77**	**41.42**	**39.52**	**39.02**
D	E	A	C	F	B
23.10	21.41	20.62	20.96	20.80	21.72
20.42	21.21	20.33	16.82	18.05	18.74
43.52	**42.62**	**40.95**	**37.78**	**38.85**	**40.46**
C	F	E	A	B	D
23.71	22.38	20.60	21.29	21.26	19.76
27.22	21.61	21.14	18.84	21.19	19.04
50.93	**43.99**	**41.74**	**40.13**	**42.45**	**38.80**
A	D	C	B	E	F
22.27	24.89	22.12	22.85	20.78	20.64
25.59	23.96	22.10	20.64	20.21	19.13
47.86	**48.85**	**44.22**	**43.49**	**40.99**	**39.77**
B	C	F	D	A	E
23.52	22.75	21.78	22.26	20.09	20.18
23.57	23.66	21.64	20.36	18.99	20.66
47.09	**46.41**	**43.42**	**42.62**	**39.08**	**40.84**

Examination of the table shews that differences are closely connected with position in the Block. It is easy to draw an entirely plausible fertility contour map on the basis of the figures, which is a fair test to shew the relationship between location and growth. This conclusion is also borne out statistically by the analysis of variance in Table XIII which shews that by far the greater part of variance can be attributed to location.

TABLE XIII.

ANALYSIS OF VARIANCE.

	Degrees of freedom.	*Sum of squares.*	*Mean squares.*
Rows ...	5	44.35	8.87
Columns ...	5	200.60	40.15
Treatments ...	5	39.08	7.81
Error ...	20	55.52	2.78
Total ...	35	339.55	

Standard error (6 plots)=4.07 or 1.6 per cent.

The standard error of the experiment for a group of six plots is 1.6 per cent, which gives considerable accuracy for judging results. The errors for the first two series of measurements were much higher (about 4 per cent), but it must be remembered that those series did not show a proper conformity to the normal population curve.

If the plots having the same treatment are grouped together and the average growth is compared with the control as 100, we get the following figures :—

A	B	C	D	E	F
100.0	105.4	103.7	102.3	99.9	98.4

As on each previous occasion, the B plots receiving a complete organic fertiliser (dung) shew the best growth. None of the effects are large; indeed, the only other result that can be regarded as significant is that for the C plots receiving a complete inorganic fertiliser. The results are rather surprising, since there have been five separate applications of fertilisers, and as an example of the amounts given [see Part I Table III] it may be stated that the E plots had received a total of well over 2 lbs. of "Ammophos 20/20" per tree. The amounts of plant nutrients given with the dung (as conventionally reckoned) are known from later analyses to have been smaller than in the other cases where chemical fertilisers were given,—especially in regard to phosphates and potash.

The simplest conclusion seems to be that the reserves in this virgin soil have so far proved, for all practical purposes, quite adequate for the growth of Hevea and have needed no assistance from outside sources. Thus the fears which were early expressed as to the poorness of the site are not being confirmed, and the disappointing results in the first months may safely be attributed to exceptionally dry weather acting in a situation abnormally sensitive to drought (i.e. young trees in an open well-drained soil). Conventional analysis tables of rubber soils are difficult of interpretation unless depth of soil is taken into account. In the present case, as in others which we have examined, great depth of weathered mineral material having easy drainage is compensating for the low figures for plant nutrients shewn by a conventional analysis of the usual acid extract of the soil. This point of view does not affect the nitrogen question however, and this may assume greater importance when the newly exposed surface soil loses the supplies associated with the humus.

The outstanding feature for emphasis is the way in which growth has evened itself as soon as the first critical stages were passed and the trees were vigorously established. The promise of some marked differences, which previous measurements suggested, has not been fulfilled. The moral is an important one and warns one to discount hasty conclusions based on early differences, which are the more easily observed when the plants are small.

Comparing the two series of measurements here reported, it seems that girth may prove a more sensitive criterion of growth than a combination of height and spread. This is fortunate, for not only is the girth measurement more direct and more easy to perform but it also concerns that part of the tree which is the focus of interest—the future tapping area.

Summary.

Two series of measurements of young rubber are reported for a manuring experiment on a new clearing; one analyses girth measurements at two years old, while the other discusses the height and spread measurements at two and a half years. None of the differences are large enough to be of practical importance, but significant effects have been produced by dung in both cases. In addition, girth was improved where nitrogen alone was given and total growth was improved by a complete chemical fertiliser, but none of the other figures are significant.

Part of the growing period has been much affected by drought and the lack of result from fertilisers might be directly associated with this in some way. Alternatively, it might be explained by the newly cleared soil having sufficient reserves for normal tree growth, rendering additions almost superfluous up to the present stage. The progress of the experiment will presently resolve these uncertainties.

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EFFECT OF COVERS AND CLEARING METHODS ON THE GROWTH OF YOUNG RUBBER TREES, II.

BY

W. B. Haines.

The previous paper * dealt with measurements of growth of Hevea made on certain blocks of the Institute's Experiment Station at Sungei Buloh under various treatments regarding covers and clearing of timber. At that time the trees were about eighteen months old. A second set of measurements of the same trees is here reported showing the changes introduced by a further year of growth. The first series showed that growth had in general been slower on plots carrying ground covers, and that this retarding effect had been lessened where timber had been left lying after the burn as compared with plots cleared in the usual way. The position of affairs is similar though partly modified in the new set of readings, but it is noticeable that early differences tend to fade out rather than to increase. The same tendency toward uniformity has been remarked for the growth on Block 6 during the same period.

The trees have now assumed the normal branched form, so that both height and spread were measured and treated for the purposes of calculation in the same way as explained in the preceding article dealing with Block 6.† The frequency curves showed a population with only minor differences from Block 6, as would be expected in a planting of the same season and on similar soil. Briefly, the figure taken as an index of total growth is height plus twice the spread. The special group representing supplies or casualties (trees 12 feet high and under) were separated from the others. Comparisons made on height alone were also examined and found to give substantially the same results as the total growth, but the latter combined figures naturally gave smoother data.

Blocks 7 & 8 (10 acres each).

The trees at two and half years of age are nearly twice as tall as at eighteen months. Thus on Block 7 the earlier measurements showed an average height for "cover" and "clean weeded" areas of 11.0 ft. and 12.1 ft. respectively. The corresponding values now are 20.1 ft. and 22.5 ft.

* R.R.I. Journal, Vol. 3, No. 1.

† This number pp. 103.

TABLE I.

Mean total growth in feet (height plus twice spread).

Rubber trees 29 months after planting.

		Cover.		Control (Clean weeded.)		Difference between cover & control
Block 7 Timber left.	Seed at Stake	37.0, 34.9, 38.6	36.84	38.5, 38.4, 40.4	39.11	6.2 per cent.
	Basket Plants	39.9, 41.2, 41.4	40.84	40.2, 43.9, 46.9	43.71	7.2 ,, ,,
	Stumps	33.7, 37.3, 41.2	38.07	41.7, 41.6, 47.9	43.71	14.8 ,, ,,
	Mean.		38.58		42.18	9.3 ,, ,,
Block 8. Cleared.	Seed at Stake	33.1, 34.5, 40.1	35.89	39.6, 39.9, 38.0	39.19	9.1 ,, ,,
	Basket Plants	35.5, 38.5, 43.6	39.21	42.0, 46.6, 39.6	42.74	9.0 ,, ,,
	Stumps	34.3, 35.3, 44.9	38.17	43.9, 41.6, 45.3	43.59	14.1 ,, ,,
	Mean.		37.76		41.84	10.8 ,, ,,

Comparisons of "total growth" (in feet) for the various plots are given in Table I, which takes exactly the same form as that previously given for the first set of measurements. For each group of three entries in the column for "cover" the first figure represents a plot having a creeper (Calopogonium), while the other two figures represent plots having shrubby covers (Crotolaria and Leucaena respectively). As in the earlier series of measurements, the clean weeded plots are in advance of those under covers, but the relative differences have diminished rather than increased. In other words earlier differences are smoothing out and becoming of less importance. Thus on the cleared land of Block 8 the difference between cover and clean weeded plots was previously 23 per cent, but this is now reduced to about 11 per cent. The differences on Block 7, where the timber has been left lying, were only about 10 per cent. at the first measurements a year ago, and the new measurements show the relative positions to be little changed.

For some reason the retardation of growth due to covers seems to be larger where stumps were used for planting than where seedlings were used. The seed-at-stake planting is still definitely behind the others, but following the general trend it has partly caught up, reducing its "handicap" by about one half. Basket plants have maintained their slight superiority over stumps on the plots with covers, but on the clean weeded plots there is little to choose between them. As in the earlier measurements the growth on clean weeded plots is the same for the cleared ground as it is for ground on which the timber is left lying.

The casualty group formed 10.3 per cent on Block 7 and 7.9 per cent on Block 8, a difference of small significance.

Block 11.

This Block is the so-called "kampong" planting experiment, where secondary growth has been allowed since burning. Part of the planting is 22 x 22 feet and part 22 x 11 feet. The trees have kept pace with other Blocks in respect of height but differences are shown in respect of branching. The average heights were :

Seed at Stake	...	19.5 feet.
Basket plants	...	20.7 „
Stumps	...	21.0 „

The corresponding figures for Blocks 6 and 7 taken at the same time were 21.7 feet and 21.3 feet respectively. The difference shown by Block 11 is scarcely significant, and could easily be attributed to the few months' difference in planting date.

The table of measurements of spread has no entry where the tree is unbranched. These, therefore, form a class of their own con-

sisting of the smaller and less mature trees and of the particular bottle-brush type which grows very tall but delays branching. On Block 11 this class formed 23 per cent of the trees while the corresponding value for Block 6 was only 15.3 per cent., showing that branching is on the whole delayed for the kampong planting. The same feature is indicated quite clearly in the figures for average spread of the normal branched population. Block 11 shows an average spread of 7.3 feet while the corresponding figure for Block 6 is 11.1 feet. It is very interesting that this effect is apparently not connected with crowding in its most obvious sense, since when the figures for the closer planting are taken separately, the average spread is not significantly different; thus, the 22 × 22 feet planting has an average spread of 7.3 ft. and the 22 × 11 ft. planting has a value of 7.2 ft. On this block the rubber has throughout maintained its dominance in respect of height, and the natural response of some plants to competing undergrowth would be a vigorous spread to overshade it. Apparently such a response is not made, but there is rather the jungle habit which is to struggle upwards for light. The simple point of view to take is that there has been a retardation of total growth, which is shown in the spread measurements rather than the height because the form of the tree under competition has the height forced at the expense of spread.

A further interesting feature of this Block is the lower incidence of *Fomes lignosus* at the present stage. I am indebted to the Pathological Division for the results of a tree to tree inspection made at about the same time as the other measurements. Whereas on Block 6 the total incidence was 6.0 per cent., on Block 11 the figure is only 2.4 per cent. The incidence of total casualties (class 12 ft. and under) is about the same for the two Blocks (9.5 per cent. and 10.3 per cent.). It may be doubted whether *Fomes* can be less prevalent in the soil under the kampong conditions than elsewhere, but the fact remains that at this stage the rubber is escaping comparatively lightly.

Summary.

Measurements of the growth of rubber trees at 29 months from planting are examined, and show that earlier differences due to conditions of cultivation are tending to diminish. Thus too much importance must not be placed upon early differences of growth, which are easily observed, without weighing factors which may come into play later.

The trees which have been planted on a Block which has been allowed to revert to secondary jungle growth have equalled other Blocks in regard to height, but they have been delayed in regard to spread (branching). The incidence of disease is also low at this stage among these trees.

A FURTHER NOTE ON THE EFFECTS OF FUNGICIDES ON THE VIABILITY OF HEVEA BUDS.

BY

R. P. N. NAPPER.

During the past year, considerable work has been carried out both in Ceylon and Malaya to determine the types and strengths of fungicides which may with safety be used for the disinfection of imported or exported budwood and budded stumps, in order that such material may comply with possible plant quarantine regulations.

The results obtained in the two countries seemed to be at variance, especially as regards the possibility of using copper sulphate as a disinfectant, and an interchange of correspondence and treated material took place between the Rubber Research Scheme, Ceylon, and the Rubber Research Institute, Malaya. As a result, a satisfactory explanation has been found for the apparently divergent views of the authorities in Ceylon and in this country.

According to the monthly reports of the Mycologist, Rubber Research Scheme, Ceylon, the first experiments in Ceylon were projected in October 1929. A year later, in the report for October 1930, it was stated that the results of the experiments so far carried out indicated that a 5 per cent. solution of copper sulphate was an effective and harmless disinfectant for both budwood and budded stumps. Co-operation with this Institute was solicited, and in November 1930 a box of budwood from clone AVROS 50 was treated according to specification at the Experiment Station, Sungei Buloh, packed, and despatched to Ceylon.

The treatments were as follows :—

(*a*) Immersion for 5 minutes in a 5 per cent. solution of copper sulphate.

(*b*) As in (*a*), but washed afterwards with water.

(*c*) Immersion for 5 minutes in a 2 per cent. solution of copper sulphate.

(*d*) As in (*c*), but washed with water.

(*e*) Control untreated.

When the box was opened on arrival in Ceylon, it was found that considerable damage had resulted from the treatments. Bud-

wood from treatment (*a*) was completely rotten; that from (*b*) and (*c*) was severely injured; while budwood from (*d*), although showing less damage than any of the other treated material, was still seriously affected by the treatment it had received. The control sticks appeared healthy, and it seemed obvious that the damage had been due to treatment with copper sulphate. Buds were taken from sticks treated by (*b*), (*c*), (*d*), and (*e*), but although budding operations were personally supervised by a research officer of the Rubber Research Scheme, Ceylon, not a single successful result was obtained even from the control sticks.

These results were in direct contradiction to those previously obtained in Ceylon, when even 5 per cent. copper sulphate solution had caused no damage to budwood or budded stumps. The results obtained in Ceylon with the Malayan budwood were however corroborated in Malaya during extensive investigations of the problem of budwood disinfection carried out at the Experiment Station, Sungei Buloh, in December 1930. The results of these investigations were published in the Quarterly Journal of the Rubber Research Institute, Vol 2, No. 4, April 1931.

In the meantime, the results obtained in Ceylon with Ceylon budwood had also been corroborated by further experiments carried out in that country at the Research Laboratories, Culloden Estate, during which budwood treated with a 2 per cent. solution of copper sulphate, packed and stored, looked quite healthy after 11 days. The box of budwood which had been sent from Malaya to Ceylon was only 9 days in transit, and yet not one healthy bud could be obtained from the whole consignment.

It was therefore suspected that the differences between the results obtained in the two countries were due to differences in susceptibility between the budwood from different clones to damage by copper sulphate. Budwood for the Malayan experiments had been taken from clone AVROS 50, while that for the Ceylon experiments had been chiefly taken from a local clone known as G. 771. Evidence pointed to clone AVROS 50 being relatively susceptible, and to clone G. 771 being relatively resistant to damage by copper sulphate.

In order to elucidate this point, is was arranged between the two research stations that a box of budwood treated with copper sulphate solution should be despatched from Ceylon to Malaya during the next Malayan budding season, and that each treatment should contain budwood from both the clones involved.

This box of budwood was despatched on May 2nd 1931, was delivered in Kuala Lumpur on May 19th, and budding operations were performed on May 20th. The results obtained were of great interest and are quoted and discussed in the following paragraphs.

Details of Treatment.

The treatments employed were as follows :—

(1) Two yards of budwood immersed in a 2 per cent. solution of copper sulphate for 5 minutes, then washed in water.

(2) As in (1), but not washed after treatment.

(3) Two yards of budwood immersed in a 1 per cent. solution of copper sulphate for 5 minutes, then washed in water.

(4) As in (3), but not washed after treatment.

(5) Two yards of budwood untreated.

In each treatment one yard (marked 1A, 2A, etc.) was of clone AVROS 50, and the other (marked 1G, 2G, etc.) of clone G. 771.

The budsticks were wrapped individually in sacking and packed in moist fibre in a wooden box. There was considerable delay in delivery, and the abnormally long period of seventeen days elapsed before the box arrived in Kuala Lumpur. When the box was opened in the nursery at the Experiment Station, the budwood was found to be very severely injured. The observations made on the condition of the budwood are summarised in Table I.

TABLE I.

The condition of the budwood, and the number of apparently healthy buds taken from each stick at the time of budding.

Treatment.	Condition of Sticks.	Strippable Buds.
1 A	Completely dead and mouldy ...	0
1 G	Severely injured ...	17
2 A	Completely dead, with rich growth of moulds ...	0
2 G	Very severely injured ...	3
3 A	In an advanced state of decomposition ...	0
3 G	1½ feet of stick dead ...	10
4 A	Completely dead and mouldy ...	0
4 G	Severely injured ...	14
5 A	Completely dead and mouldy ...	0
5 G	1 foot of stick dead ...	8

Results of Budding from the Treated Material.

The buds were worked on uniform vigorous stocks in a 2½ years old nursery. The tapes were removed after 16 days, and the condition of the budpatch determined, and at the expiration of a further period of a month a second and final examination was made.

The dates of treatment, budding, and inspection, and the details of successful buddings obtained, are summarised in Table II.

TABLE II.

Summary of the operations performed on the box of budwood, and of the results obtained.

Budwood treated	...	May 2nd.
Budding operations performed	...	May 20th.
Tapes removed and first inspection made	...	June 5th.
Second inspection made	...	July 5th.

Treatment	Number of Buds cut.	Number of Buds used.	Successes			
			1st inspection		2nd inspection	
			No.	Per cent	No.	Per cent
1 G	17	15	11	73	10	64
2 G	3	3	0	0	0	0
3 G	10	8	4	50	4	50
4 G	17	16	6	38	6	38
5 G	8	7	5	71	5	71

Analysis of Results.

It is immediately obvious from an examination of Tables I and II that budwood from clone AVROS 50 is considerably more susceptible to injury than budwood from clone G. 771. Not only is the effect of copper sulphate on the former clone so much more intense than on the latter that not one strippable bud of AVROS 50 could be found on any of the treated sticks, but even the control stick of that clone had succumbed after the long period of transit, while two thirds of the control stick of clone G. 771 still remained healthy.

These results support those obtained with the treated budwood sent from Malaya to Ceylon in November 1930 and explain why they

differed so considerably from results previously obtained with Ceylon budwood.

No great significance was expected of the results from the treated sticks of clone G. 771 since the number of available buds was so small, but the actual differences obtained in successes between the several treatments were considerable enough to warrant the following deductions :—

(*a*) Treatment 2 G was the strongest.

(*b*) Treatments 1 G and 3 G, in which the budwood was washed with water after treatment, were much weaker than treatments 2 G and 4 G, in which the budwood was not subsequently washed.

(*c*) That the results obtained from treatments 1 G and 3 G were comparable with those obtained from the untreated control.

Deduction (*a*) would be expected *a priori.*

Deduction (*b*) agrees with the results obtained in this laboratory and published in the paper already referred to (Q.J. of R.R.I., Vol. 2, No. 4, April 1931), in which budwood of a different clone and a large number of different fungicides were used.

Deduction (*c*) agrees with the results obtained in the laboratories of the Rubber Research Scheme, Ceylon, which led to the statement in October 1930 that a 5 per cent. solution of copper sulphate appeared to be a harmless and efficient disinfectant for budwood and budded stumps.

Thus the observations made on the treated budwood sent from Ceylon to Malaya during May 1931 have corroborated the main observations previously made in each of these two countries on the efficiency of copper sulphate as a disinfectant for budwood and budded stumps, and have indicated that the lack of agreement between the results obtained has been due to the differences in susceptibility to damage by this fungicide between the budwood of the different clones employed.

The observations also indicate that, in the event of the requirements of plant quarantine regulations becoming more exacting, it may be desirable to lay down a further series of experiments on the disinfection of imported and exported budwood and budded stumps using a single fungicide and a range of clones, to supplement those already carried out with a range of fungicides and a single clone, so that recommendations for the treatment of any particular consignment may be given with confidence.

At the moment however the necessity for such experiments does not arise and pressure of work of more immediate importance precludes for a time the possibility of further investigation of the problem in this laboratory.

Summary.

1. Considerable discrepancies have been apparent between results obtained in Ceylon and in Malaya as to the efficiency of copper sulphate as a disinfectant for budwood and budded stumps.
2. The results were consistent in each country, and it was suspected that the discrepancies were traceable to differences in susceptibility to damage by copper sulphate between the budwood used for experiment in Malaya and that used in Ceylon.
3. The budwood used in Malayan experiments was taken from clone AVROS 50, and that used in Ceylon experiments from a local clone known as G. 771.
4. A box of budwood, containing sticks of both these clones treated (in duplicate) in various ways with copper sulphate, was prepared in the laboratory of the Rubber Research Scheme, Ceylon, and despatched to the Rubber Research Institute of Malaya.
5. Budding results obtained with this material showed that budwood from clone AVROS 50 was much less resistant than budwood from clone G. 771 to injury by copper sulphate, and that the effect of the treatments was of the same type on both clones but different in degree.
6. Should the problem of the disinfection of imported and exported budwood and budded stumps assume a greater importance, the need is indicated for the investigation of the relative susceptibilities of the more popular clones to injury following disinfection by various fungicides.

THE IDENTITY OF THE FUNGUS CAUSING WET-ROOT ROT OF RUBBER TREES IN MALAYA.

BY

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Through the kindness of Miss Wakefield, of the Kew Herbarium, of the Director of the Buitenzorg Botanic Gardens and of the Head of the Pathological Department of the Rubber Research Institute of Malaya, who provided the requisite herbarium-material and supplied most useful information, I have been enabled to confirm beyond doubt the identity of the causal fungus of the wet-root rot in Malaya with the "roode wortelschimmel" of Java. The fungus is a species of Ganoderma and must be known as *G. pseudoferreum* (Wakef.) v. O. et St.

It was first described in 1918 by Miss Wakefield from an immature fruit-body found associated with typically diseased tissue and from some abnormal fructifications developed in artificial culture, which Belgrave had sent to Kew from Malaya for identification (1). The description was necessarily tentative, to provide a name, and Miss Wakefield remarked that the fungus was probably a Ganoderma though the point could not be decided in the absence of spores. Belgrave added some further details in the following year in his bulletin on the disease (2).

In 1923 v. Overeem and Steinmann described the "roode wortelschimmel" which attacks rubber trees in Java (3). They obtained plentiful mature specimens of the fungus, which was unquestionably a Ganoderma and, following Lloyd's description of *Fomes ferreus* Berk., they referred it to that species under the combination of *G. ferreum* (Berk.) v. O. et St. In 1925 v. Overeem announced that this identification was wrong owing to a mistake on the part of Lloyd and, judging from Miss Wakefield's diagnosis of *F. pseudoferreus* and Belgrave's account of the disease in Malaya that the Java material must belong to the same species, he re-described it fully as *G. pseudoferreum* (Wakef.) v. O. et St. (4). An illustrated description is given by Steinmann in his book on the diseases of *Hevea brasiliensis* (5).

v. Overeem and Steinmann did not refer to Miss Wakefield's type and for several reasons their identification has not been consid-

ered proven (6). The symptoms of the disease are somewhat different in the two countries. Whereas in Java fruit-bodies are commonly developed from infected rubber trees they are very seldom found in such connection in Malaya. Furthermore, Belgrave claimed to have grown fruit-bodies of *F. pseudoferreus* Wakef. from colourless subglobose spores very unlike those of Ganoderma. On this last point I am unable to shed any light.

I have examined microscope-sections of the type-material of *F. pseudoferreus,* which Miss Wakefield sent from Kew. They show the characteristic hyphae of Ganoderma, the characteristic crust on the upperside of the pileus, and in one tube there were some thirty basidiospores of the Ganoderma-kind. The spores might, of course, have been blown in from outside but it is peculiar in that case that they should have entered into one tube only and be found at the upper end, which strongly suggests rather that the fruit-body was just beginning to spore : a late commencement of sporing has been reported in other species of the genus (7). Miss Wakefield's suspicion is thus confirmed.

I have also examined a collection from Java identified by v. Overeem himself, as *G. pseudoferreum,* namely Herb. Hort. Bot. Bog. No. 843. Microscopically the specimens agreed in all respects with Miss Wakefield's type and there are no discrepancies in the macroscopic characters as given in her diagnosis.

Furthermore I have compared both these collections with living material from Singapore and other parts of Malaya and with fruit-bodies, developed in close connection with the diseased roots of rubber trees, which were sent from the Rubber Research Institute of Malaya. They agree in all points and I have drawn up the following description from the Malayan material; it will be seen to correspond exactly with that of v. Overeem and Steinmann, even to the strong smell of the fresh growing fruit-bodies and the tendency to proliferate at the margin of the pileus.

The species is common on dead stumps in the Singapore Botanic Gardens, where it brings about the characteristic red discoloration of the cortex of the dead roots, and also in the lowland forest of Malaya. I have found it parasitic at the base of several large trees in the forest in Johore and Pahang, and on Myristica, Pterocarpus and *Arenga saccharifera* in Singapore. v. Overeem records Metroxylon, Albizzia and the Durian as other hosts on which it is parasitic. It would be remarkable moreover if a fungus so abundant in Java were absent from Malaya.

The species comes very close to the well-known *Ganoderma applanatum* (Pers.) Pat.; it may indeed prove a variety. The spores are identical with those of var. *tornatum* (Pers.) which Humphrey has recently described (7). The only difference which I have noticed

lies in the development of a fairly distinct palisade by the hyphal ends on the upperside of the pileus in *G. pseudoferreum* and which is said to be absent from *G. applanatum*. A special study will be needed to decide this point, so that the two species must be retained apart for the present.

It must be remarked that Petch has shown that v. Overeem's citation of *Poria hypobrunnea* Petch, *P. hypolaterita* Berk., and *Trametes Theae* Zimm. as synonyms of *G. pseudoferreum* is false, and any question of priority among these names therefore does not affect the species under discussion (6).

Ganoderma pseudoferreum (Wakef.) v. O. et St.

Sessile or substipitate, dimidiate, applanate, horizontal or ascending, often imbricate, up to 22 cm. in radius, 31 cm. wide.

Upperside glabrous or very finely velutinate, rather dull, *sulcate,* often irregularly tuberculate, *fuscous-umber or blackish with crowded cinnamon, brownish-olivaceous or khaki-coloured narrow wavy zones, and with a conspicuous bright chestnut-brown subresinaceous zone* (2—10 mm. wide) *near the margin;* eventually dull brown from the spores : *margin white,* thick and tumid at first, becoming thin, subacute and often lobed or proliferating small pilei.

Stem subcylindric or flattened, expanding gradually into the pileus, up to 6 cm. long × 1.5 — 8.5 cm. wide, concolorous with the pileus.

Flesh 16 — 45 mm. thick at the base, relatively thin in the mature pilei (5 — 10 mm. thick at halfway to the margin), *cinnamon-bay-brown,* darker over the tubes and *mostly very pale near the upperside,* darkening with age, with narrow alternating dark and light zones, *developing thin fuscous or blackish crustaceous lines,* 0.2 — 1 mm. thick, from the base to the margin (as seen in radial section); *with a thin blackish crust,* 0.2. — 0.5 mm. thick, *on the upperside.*

Tubes up to 10 mm. long at the base, *fuscous or blackish brown,* drying concolorous with the flesh; *pores white,* small, circular, entire, 100 — 150 μ wide, with dissepiments 40 — 100 μ thick.

Spores dark ferruginous in the mass, ellipsoid, subtruncate, at one end, appearing minutely echinulate, 6 — 7.5 × 4.5 — 5 μ, with one large gutta, 1.5 — 2.5 μ wide.

Smell strong, like mice and cheese, especially when kept for a few days.

The pale-coloured flesh in the upper half of the pileus appears to be as characteristic as the variously coloured zones on the surface, but both features disappear with age. The zones are ultimately obscured by the thick deposit of spores which settle on the pilei, and the flesh darkens in colour as the crustaceous lines develop centrifu-

gally. The upperside is not shining or laccate, as in *G. lucidum,* though the chestnut-coloured zone near the margin is sometimes sticky and subresinaceous.

The thickness of the flesh varies considerably according to the size of the primordia, but well-developed pilei are always relatively thin and never become hoof-shaped.

The growth of the fruit-bodies appears to be rather slow, at least three or four months being required for the pilei to reach a size of 12—15 cm. in radius. Sporing begins at a late stage, not until the pilei are 5—14 cm. in radius and the tubes are 3—8 mm. long. Fruit-bodies which have developed in open situations often assume irregular shapes, since their growth is interrupted by spells of dry weather: they consist of the original primordial knob, 1—6 cm. in diameter, at the end of which other knobs, lobes or rudimentary pilei have developed with or without intervening short layers of tubes. These abortive specimens are seldom fertile, but they can be identified from the characteristic colouring. They are the forms most likely to be met with on rubber estates.

The fruit-bodies always develop low down near the base of infected trees or from the roots, and similarly on dead stumps. Those of *G. applanatum,* on the other hand, may develop from a considerable height, up to twenty feet or more above the ground.

Summary.

The identification of the fungus causing the wet-root rot of rubber trees in Malaya with that of the red-root disease in Java, which was first made by v. Overeem and Steinmann in 1923, has been confirmed through examination of authentic herbarium-material. The fungus stands as *Ganoderma pseudoferreum* (Wakef.) v. O. et St.

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3. v. Overeem, C. and Steinmann, A. *Archief voor de Rubbercultuur,* **7e,** 1923, 453.
4. v. Overeem, C. *Bull. Jard. Bot. Buit.* Ser. **3, 7,** 1925, p. 436.
5. Steinmann, A. *De Ziekten en Plagen van Hevea brasiliensis,* Buitenzorg, 1925.
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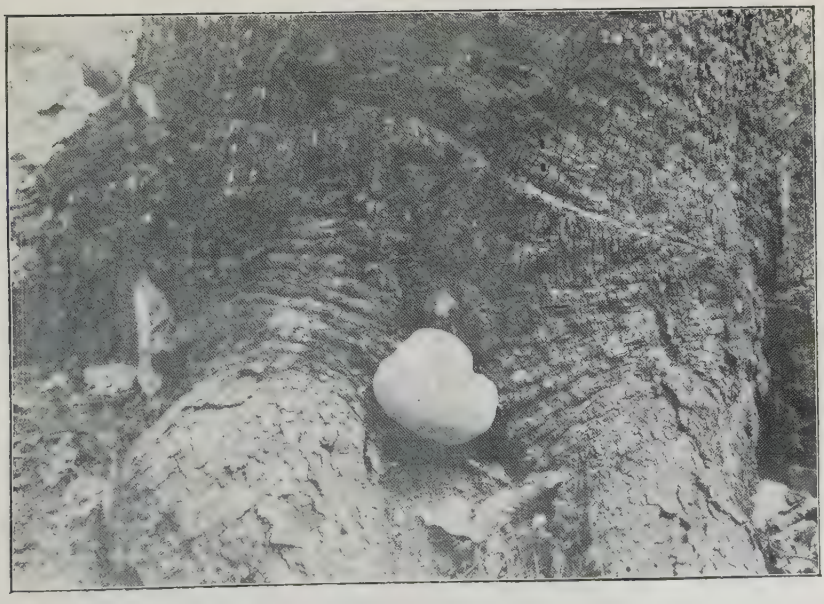
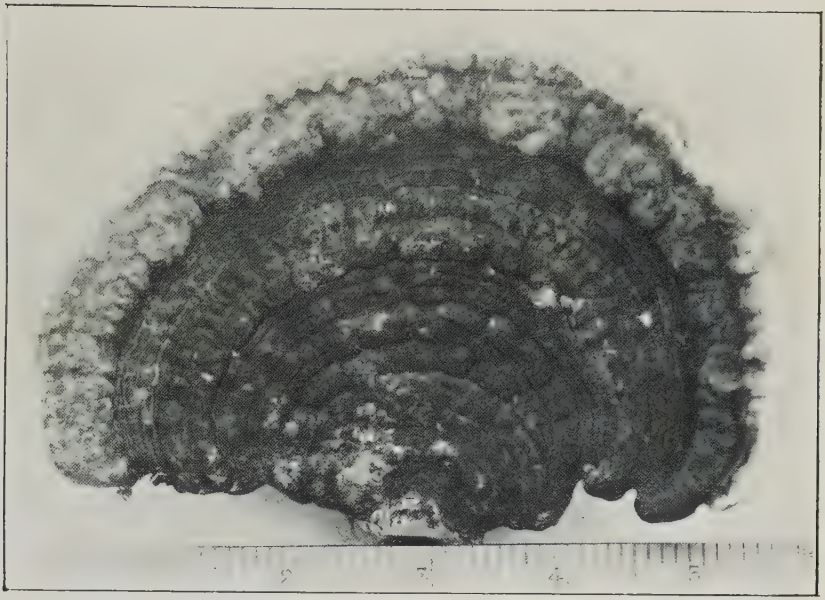
7. Humphrey, C. J. *Phil. Jour. Sci.,* 1931, **45,** p. 483.

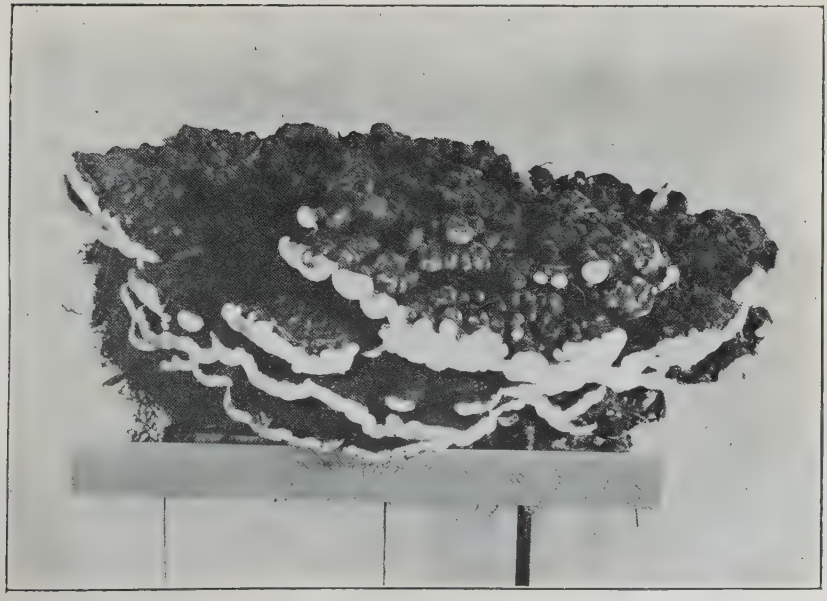
Shows the round bulbous early stage in the development of the fructification of *F. pseudoferreus.*



Enlarged view of Photo No. 1.



Shows typical single hoof-shaped form of *F. pseudoferreus* fructification.



Shows the common imbricate form of *F. pseudoferreus* fructifications.

EDITORIAL.

This number completes Vol. 3 of the Journal. Another number will appear shortly which will be published as No. 1 of Vol 4.

Variation in Plantation Rubber.

In spite of the considerable amount of investigation which has been carried out in relation to causes of variability of plantation rubber, there still appears to be considerable justification for complaints by rubber manufacturers on the score of lack of uniformity. In order to overcome such variability the manufacturer has to adopt various methods of batching or mixing the rubber from different estates or even the individual cases from the same estate.

It will be realised that the present methods of marketing of raw rubber cannot take into account this variability, since the appearance of the raw material on which its market value is based does not indicate in any way the behaviour of the product during the various processes, including plasticizing and vulcanisation, to which the material is subjected by the rubber manufacturer.

The principal variations of importance to the manufacturer are (i) rate of vulcanisation, (ii) plasticity, (iii) ageing properties.

Although the paper published in this journal by Messrs. R. O. Bishop and R. G. Fullerton deals only with variability in rate of vulcanisation, it can be stated with considerable certainty that the other properties of the raw material will also show similar variation due primarily to lack of uniformity in methods of preparation or to insufficient bulking of the raw material—latex.

Considerable attention has been paid recently in the technical press to this and related problems, such as the manufacturers' requirements in relation to raw rubber. Although it has to be admitted that "pretty" rubber does not necessarily indicate uniformity or the existence of other qualities required by the manufacturer, it can be stated generally that rubber of good even appearance at least indicates care in preparation in the estate factory. Such care in preparation is also more likely to result in greater uniformity.

Secondly, "pretty" rubber does not necesssarily cost more to prepare since an even sheet of uniform thickness can be dried and smoked in a shorter period with less consumption of fuel than an irregular sheet of poor appearance with thick edges and corners. Also, pale crepe rubber must conform to a definite colour

standard for certain purposes, such as the manufacture of dipped goods requiring a transparent colourless appearance.

Uniformity from the manufacturers' point of view in relation to the behaviour of the raw product during vulcanisation depends to a large extent on the proportion of serum solids remaining in the raw rubber after machining and drying. Hence, in order to obtain greater uniformity, it is essential that these serum solids be maintained in constant proportion in the dried rubber or be reduced to a minimum by washing and machining of the coagulum before it is dried.

For this reason, thin crepe is much more uniform than smoked sheet, since the amount of serum solids has been reduced to a minimum by washing and machining before drying, while the finished thin wet crepe dries rapidly and biological changes during drying which also cause variability are reduced to a minimum.

On the other hand, sheet rubber, whether air-dried or smoked, is likely to be more variable, since on different estates and even on the same estate from day to day, variable factors such as methods of bulking of latex, dilution of latex, thickness of final sheet, machining on the day of or the day following coagulation and differences in methods of drying and smoking, may be introduced.

Uniformity in method of preparation, commencing with tapping, bulking of all latex and subsequent treatment of latex and coagulum is essential in order to obtain a uniform product.

If such uniformity is unobtainable on any estate, the only alternative is to mix the latex or coagulum from different estates.

The uniformity of re-milled blanket crepe, which is stated to exist, is due to the mixing carried out in the re-milling factories of large quantities of rubber from various small holdings. The comparative uniformity of Fine Hard Para—once the world's premier raw rubber is due to the fact that each ball is made of a latex dried and smoked over a large number of days, so that variable factors introduced in the drying and smoking of each day's supply of latex are averaged in each ball.

The preparation of blanket crepe on an estate would not necessarily result in a more uniform rubber in the daily crop, unless the other factors in preparation remain constant and uniform.

The conversion of estate smoked sheet into blanket crepe in order to make a more uniform rubber would involve extra cost to the estate and would not result in a higher market value (in fact the price paid by the buyer would almost undoubtedly be lower) with present buying methods. Hence, the individual estate must continue to prepare sheet, which is at present one of the cheapest forms of manufacture of raw rubber, or a crude coagulum which together with that of other adjoining estates is milled into blanket

crepe in central factories. In the writer's opinion, this is the only solution of the uniformity problem, from the producers' point of view. The only alternative is to leave the batching or mixing to the manufacturer.

Improvements in factory machinery, as indicated in Manual No. 3, recently published by this Institute, and more uniform methods of drying and smoking will however result in a greater uniformity of the raw product.

If special types of raw rubber are required for specific purposes, new marketing methods will probably have to be introduced, since the average buyer will not be able to determine from appearance the quality of the product which he buys. This will entail direct purchase between producer and consumer.

The Effect of Carbohydrates on the Vulcanisation of Rubber.

In relation to the investigation of the non-caoutchouc constituents of latex, which is essential to a complete understanding of the properties of raw rubber and latex and their application to various commercial uses, the presence of simple carbohydrates (sugars) in the latex of the rubber tree has been recorded by various investigators.

The fermentation of latex, resulting in the formation of bubbles in sheet rubber is due primarily to the presence of sugars. The addition of a small quantity of sugar to latex, combined with delayed coagulation, results in a prolific production of such bubbles.

The anaerobic process of coagulation is also closely related to the amount of sugar present in the latex.

In order to ascertain the influence of the various constituents of latex on the prepared rubber, the indirect method of attack adopted in the investigations described by Messrs. Bishop and Rhodes, in which various sugars are added in different proportions to the different types of raw rubber is frequently of considerable value.

The results of these investigations indicate that the various sugars have an influence on the vulcanising properties of raw rubber, but that this influence differs according to the type of rubber. These opposite effects with different types of rubber indicate that the action of the sugars is influenced by other constituents present in the raw rubber.

Other more important work precludes a continuation of this particular investigation at the present time, but it is hoped to continue the work at a later date.

Quebrachitol.

Various investigators have recorded the presence of Quebrachitol (1-methyl inosite) in the latex of *Hevea Brasiliensis* and in the rubber prepared therefrom. The effect of the presence of this substance on the vulcanisation properties of raw rubber has also been investigated.

In the acid coagulation of latex, Quebrachitol is distributed between the coagulum and the residual serum.

It was considered that possible commercial applications might be discovered for the quebrachitol remaining in the serum after coagulation and it was decided to prepare on a semi-commercial scale sufficient quantities of the product for distribution among chemical manufacturers who might be interested. The investigation of the possible commercial applications of the product is beyond the scope of the work of this Institute.

It is pleasing to record however that a number of manufacturers of chemicals are showing considerable interest in the product, although it is not possible at this stage to state whether any results of value will accrue.

In the article by Messrs. E. Rhodes and J. L. Wiltshire in this Journal, the economic aspects of the commercial preparation of the product are discussed. No further work will be carried out unless and until some indication is obtained that the product is likely to have some commercial application.

Outbreaks of Fire in Smoke Houses.

The article on "Outbreak of Fire in Smoke Houses," which have been of somewhat frequent occurrence during the last year, indicates the probable cause of such outbreaks.

Figures received from various Insurance Companies, which are not published, show the heavy losses incurred by such companies which are seriously concerned over the problem.

The greater attention which is being devoted to factory practice on estates and the results of investigations show the necessity of a better control of temperature, ventilation and smoking in the drying of sheet rubber. It is unfortunate that the present slump does not permit of the adoption of such improved control on many estates at the present time. Small improvements in respect of ventilation and control of smoke house furnaces have however already resulted in more rapid drying and smoking and reduced consumption of wood fuel on a number of estates.

Soils at the R.R.I. Experiment Station.

The results of an investigation of the soil at the Institute Experiment Station at Sungei Buloh are described by Dr. W. B. Haines and Mr. C. G. Akhurst.

The investigation discloses three main types of soil on the area already opened.

From an inspection of the jungle reserve, the larger portion consists of the detrital type which is predominant in the area already planted, although the hill soils are also represented. Although the growth of rubber trees is slow in the first two years due to the light texture of the soil, particularly if prolonged dry weather is experienced as in 1929 and 1930, subsequent growth is more rapid and normal.

Plantation Sheet Manufacture (Manual No. 3).

Attention is drawn to the recent publication of this Manual on Plantation Sheet Manufacture. The opinion appears to be held in some quarters that a study of the economics of factory practice is outside the scope of the chemical work of this Institute. I consider it desirable to emphasize here that the investigations which formed the basis of this Manual, are due to a widespread demand among estate managers for such information. Evidence of such a demand can be seen in the enormous amount of correspondence for advice on the subject received at the Institute. It is essential that the staff of the Institute should, as far as possible, bear in mind the economic aspects of the results of all investigations, if these are to be of practical value and application. Estate factory practice has developed from the early days of the plantation industry on somewhat unscientific and uneconomic lines, with little co-ordination between the engineering side and actual requirements.

This situation has naturally been aggravated by the high prices of rubber in the past, which have not necessitated the close attention now essential to problems of cost and saving of labour.

VARIATION IN PLANTATION SHEET RUBBER.

BY

R. O. Bishop and R. G. Fullerton.

Examination of Exhibition Samples.

An examination of the vulcanisation properties of samples of smoked sheet exhibited at the Malayan Agri-Horticultural Exhibition in August 1931 led to the collection of data summarised in Table I.

Procedure. Samples of not less than 5 lbs. were taken at random from each case of 224 lbs. and vulcanised under the standard conditions now adopted by the Institute and described in the appendix. In the Table are also included the results of smoked sheet prepared in August and collected from two estates which did not exhibit. Columns 1 and 2 give serial numbers referring to the various estates and column 3 gives the thickness of the smoked sheet. Column 4(a) states the time of cure in minutes giving the maximum tensile strength at break while column 4(b) gives the maximum tensile strength at break in kilogrammes per square millimetre. A true comparison, however, of the tensile properties of the sample is obtained by reference to column 5 which states the tensile strengths obtained at an elongation of 650 per cent when the samples are vulcanised under uniform conditions, viz: at a cure of 80 minutes. This value is termed the "modulus."

Results. From the analysis of the results we find by comparison of the coefficients of variation (C. of V.) given at the foot of each column:—

(1) The variation in thickness is decidedly high.

(2) The variation in rate of cure is 14 and the average rate of cure lies between 80 and 90 minutes.

(3) There is considerable uniformity in the values for the maximum tensile strength at break.

(4) The variation in modulus is high.

Smoked Sheet.

Samples Exhibited at M.A.H.A. Exhibition 1931.

TABLE I.

1	2	3	4 (a)	4 (b)	5
R.R.I. Ref. No. H.	Estate No.	Thickness of smoked sheet mm.	Cure giving maximum tensile strength at break Mins.	Maximum tensile strength at break Kgs/mm²	Tensile strength at 650% elongation at 80 minutes cure Kgs/mm²
848	1	1.89	120	1.55	—
849	2	2.34	90	1.46	0.62
850	3	2.81	80	1.49	1.29
851	4	3.84	80	1.51	0.88
852	5	3.23	80	1.56	1.08
853	6	3.96	80	1.36	1.04
854	7	3.56	90	1.66	0.69
855	8	3.38	90	1.51	0.52
856	10	2.64	90	1.49	0.77
857	12	3.44	90	1.58	0.60
858	13	4.25	80	1.47	0.99
859	14	4.33	70	1.52	0.94
860	15	3.93	90	1.32	0.62
861	16	3.56	80	1.49	0.99
862	17	2.36	80	1.50	1.00
863	18	3.88	120	1.39	0.48
864	19	3.18	90	1.47	0.77
865	20	2.44	80	1.45	0.64
866	21	4.60	70	1.40	0.76

1	2	3	4 (a)	4 (b)	5
R.R.I. Ref. No. H.	Estate No.	Thickness of smoked sheet mm.	Cure giving maximum tensile strength at break Mins.	Maximum tensile strength at break Kgs/mm²	Tensile strength at 650% elongation at 80 minutes cure Kgs/mm²
867	23	3.22	90	1.50	0.77
868	24	2.82	90	1.34	0.55
869	25	3.96	80	1.44	1.10
870	26	3.35	70	1.42	0.69
871	27	3.79	70	1.21	0.79
872	29	4.12	80	1.46	0.88
873	30	2.69	90	1.41	0.72
874	31	3.99	90	1.46	0.62
875	32	3.00	60	1.37	—
876	33	2.38	80	1.53	0.91
877	35	2.42	80	1.12	0.56
878	36	3.20	80	1.45	0.71
879	38	3.71	80	1.53	0.87
880	39	2.82	80	1.50	0.84
881	41	3.79	80	1.45	0.67
882	42	3.73	80	1.47	0.82
883	43	2.86	90	1.31	0.58
884	44	2.93	80	1.28	0.59
885	45	3.41	80	1.22	0.43
886	46	2.95	80	1.44	0.75
887	47	3.19	70	1.30	0.65
888	48	3.51	70	1.37	0.83

1	2	3	4 (a)	4 (b)	5
R.R.I. Ref. No. H.	Estate No.	Thickness of smoked sheet m.m.	Cure giving maximum tensile strength at break Mins.	Maximum tensile strength at break Kgs/mm²	Tensile strength at 650% elongation of 80 minutes cure Kgs/mm²
889	49	2.62	80	1.34	0.62
890	50	3.50	80	1.46	0.79
891	65	3.06	80	1.36	0.74
892	66	3.43	105	1.27	0.46
1031	67	—	90	1.32	0.82
—	68	2.81	90	1.48	0.78
	Mean = 3.28 S.D. = 0.604 C. of V. = 18		Mean = 83 S.D. = 11.14 C. of V = 14	Mean = 1.43 S. D. = 0.104 C. of V. = 7	Mean = 0.76 SD. = 0.185 C. of V. = 24

$$\text{S.D.} = \sqrt{\frac{\Sigma d^2}{n}} \qquad \text{C. of V.} = \frac{100 \times \text{S.D.}}{\text{Mean}}$$

Discussion. The most illuminating of these results is No. 4 which shows that the samples vary in their response to vulcanisation and exhibit a significant lack of uniformity.

Eaton and Bishop [1] made a similar study of samples of smoked sheet collected from the Malayan Agri-Horticultural Exhibition, 1927. Although the technique adopted at that time for mixing and vulcanisation differed from our present practice, a comparison of the results on a common basis shows the same order of variation.

As an indication of the degree of variation which may be obtained in uniform rubber due to methods of vulcanisation adopted, we quote in Table II the results obtained for different portions of a sheet of sole crepe selected at random from a case of 100 lbs., prepared by one estate, whose crepe invariably fetches top market price. In sampling, the sheet of crepe was rolled tightly into a cylinder and eight samples of 200 grammes each taken by cutting sections perpendicular to the axis. The end portions were neglected. From each of the eight portions, a mix was prepared and the eight mixes vulcanised separately at 100 minutes. Each mix gave four portions for vulcanisation from each of which two rings were taken for testing. The Table quotes the loads, in kilo-

TABLE II.

Sole Crepe.

Loads in Kgs/mm² at 650% elongation at 100 minutes cure.

Mix No.	Loads.				Mean.
1	0.96	0.99	0.97	0.96	0.97
	0.96	0.99	0.97	0.99	
2	0.92	0.92	1.01	0.91	0.93
	0.92	0.91	0.95	0.94	
3	0.98	0.95	1.01	0.97	0.98
	0.94	0.93	1.05	1.01	
4	0.86	0.84	0.90	0.88	0.85
	0.87	0.84	0.87	0.85	
5	0.94	0.93	0.97	0.96	0.94
	0.93	0.92	0.90	0.95	
6	1.02	0.98	1.02	1.04	0.97
	0.99	0.95	0.97	0.96	
	Mean = 0.95				
	S.D. = 0.05				
	C. of V. = 5				

grammes per square millimetre, obtained at an elongation of 650 per cent. The analysis of the figures given at the foot of the Table shows that the variation in the values obtained is very low, the coefficient (C. of V.) being 5 as compared with a coefficient of 24 for the M.A.H.A. Exhibition samples.

Examination of Rubber from Selected Estates.

The nature of the results recorded above led us to investigate the variation in rubber prepared on the same estate at different times. From eight of the estates on the M.A.H.A. Exhibition list further cases of smoked sheet of 224 lbs. each were collected from crop manufactured early in November. The methods of sampling the cases were similar to those adopted in August and the two sets of results are presented for comparison in Table III. It will be seen that only in one instance—that of estate No. 4—has the rate of cure remained unaltered, while for estates Nos. 26 and 27, rubber which had in August a rate of cure higher than the average is now in November lower than the average, the difference being 20 minutes. In this connection it should be noted that in August the sheets were very much thicker and less uniform in thickness than those prepared in November. In the other samples examined, the rate of cure has altered to the extent of 10 minutes. The values for maximum tensile strength at break have not substantially altered. The extent of the changes may be appreciated by reference to the modulus figures in column No. 4.

TABLE III

Comparison of August and November Sheet.

1	2		3 (a)		3 (b)		4	
Estate No.	Thickness of smoked sheet mm.		Cure giving maximum tensile strength at break Mins.		Maximum tensile strength at break Kgs/mm²		Tensile strength at 650% elongation at 80 minutes cure Kgs/mm²	
	Aug.	Nov.	Aug.	Nov.	Aug.	Nov.	Aug.	Nov.
8	3.38	3.03	90	80	1.51	1.37	0.52	0.61
4	3.84	3.59	80	80	1.51	1.25	0.88	0.72
67	—	—	90	100	1.32	1.32	0.82	0.49
26	3.35	3.03	70	90	1.42	1.28	0.69	0.58
27	3.79	3.05	70	90	1.21	1.43	0.79	0.42
68	2.81	2.81	90	80	1.48	1.33	0.78	0.83
14	4.33	3.25	70	80	1.52	1.38	0.94	0.87
12	3.44	2.98	90	80	1.58	1.45	0.60	0.67

To ascertain to what extent the changes observed might be due to methods of sampling, cases were collected at random from estate No. 68, and an examination made of portions drawn from different parts of each case. Three cases of 224 lbs. each were taken corresponding to different crop dates. The results summarised in Table IV indicate that there is a very great lack of uniformity in the rubber in cases Nos. 1 and 2 collected in August, while that in case No. 3 collected in November may be said to be almost uniform in quality since the variation in load is within the limits of experimental error (vide appendix).

TABLE IV.

Variation in a Case of 224 Lbs.

Sheet vulcanised under standard conditions at 90 minutes.
Load per square mm. determined at 650% elongation.
Case No. 1 from sheet prepared during 1st week in August.
Case No. 2 from sheet prepared during 4th week in August.
Case No. 3 from sheet prepared during 1st week in November.

Case 1. Load Kgs/mm²	Case 2. Load Kgs/mm²	Case 3. Load Kgs/mm²
1.48	1.31	1.09
1.53	1.21	1.07
1.44	1.16	1.09
0.71	0.96	1.03
0.70	1.07	1.07
		1.09
Mean = 1.17	Mean = 1.14	Mean = 1.07
S.D. = 0.40	S.D. = 0.12	S.D. = 0.02
C. of V. = 34	C. of V. = 11	C. of V. = 2

Since we were aware that factory practice on estate No. 68 was in process of alteration during the period August/November, we decided to extend our investigation to the examination of cases of smoked sheet prepared in November from three estates

among the M.A.H.A. exhibitors on which we know that good supervision governs manufacture and attention is paid to the processes of bulking the latex, coagulation, machining and drying with a view to securing a uniform product. As before, samples were drawn from different portions of a case and the loads determined at 650 per cent. elongation when cured for 80 minutes. The results are presented in Table V. The coefficients show that the variation in the case collected from estate No. 12 is almost of the same order as that obtained for the uniform sample of sole crepe referred to in Table II. On estates No. 14 and 5, however, even when allowance is made for experimental error, the variation is much higher, and in the case of estate No. 5 is almost double that of estate No. 12. Results have been selected to illustrate in Figures 1, 2 and 3, the differences obtained for samples drawn from two different portions of the same case. The curves show the representative stress/strain relationship for each sample.

TABLE V.

Variation in a Case of 224 Lbs.

Loads at 650% Elongation at 80 minutes cure—Kgs/mm².

Estate No. 12.			Estate No. 14.			Estate No. 5.		
0.66	0.78	0.64	0.72	0.66	0.82	0.52	0.54	0.61
0.65	0.70	0.71	0.71	0.71	0.91	0.52	0.59	0.68
0.70	0.70	0.67	0.71	0.70	0.88	0.53	0.50	0.66
0.63	0.72	0.75	0.71	0.69	0.77	0.53	0.56	0.73
0.63	0.68	0.76	0.70	0.66	0.85	0.59	0.58	0.74
0.72	0.66	0.80	0.65	0.69	0.89	0.59	0.58	0.71
Mean = 0.70			Mean = 0.75			Mean = 0.60		
S.D. = 0.05			S.D. = 0.08			S.D. = 0.08		
C. of V. = 7			C. of V. = 11			C. of V. = 13		

Comparisons Based on Technical Mixes.

In accordance with the practice of most modern investigators, and as advocated by Martin in his remarks on the evaluation of raw rubber[7], it was decided to ascertain the extent of the variations when the rubber was vulcanized in a technical mixing containing an accelerator. For this purpose, as an initial step it was decided to use the "Captax" mix which is typical of American compounding practice. Its composition on a weight basis is as follows:—

100 parts Rubber
6 „ Zinc oxide
3.5 „ Sulphur
0.5 „ "Captax" (mercaptobenzothiazole).

The August and November smoked sheet from four estates were compared in this mix, by vulcanising for 40 minutes at a temperature of 126°C and determining the load in kilogrammes per square mm. at an elongation of 650 per cent. Table VI gives the results obtained for the same samples of sheet according to our standard procedure and using a rubber and sulphur mix, while for comparison are given the results obtained with the corresponding "Captax" mixes.

TABLE VI.

Estate No.	RUBBER: SULPHUR MIX Load at 650 per cent elongation cured for 80 minutes at 149°C Kgs/mm²		"CAPTAX" MIX Loads at 650 per cent elongation cured for 40 minutes at 126°C Kgs/mm²	
	August	November	August	November
26	0.69	0.58	0.61	0.83
27	0.79	0.42	0.95	0.87
12	0.60	0.67	0.43	1.00
14	0.94	0.87	0.88	1.33

The differences obtained under the two methods of procedure are more readily appreciated by reference to Figures 4 to 7 (a) and (b) showing the stress/strain relationship for each vulcanised sample. Confirming the results of discussions which we have had with representatives of various large manufacturing concerns, it is evident that it is a difficult matter to correlate the

results obtained with a simple rubber-sulphur mix with those obtained with a technical mix containing "Captax." In the case of estate No. 26—vide Figures 4 (a) and (b)—the relationship between August and November rubber as shown in a rubber-sulphur mix is completely reversed in a "Captax" mix. The difference in moduli of rubber from No. 27 for a rubber-sulphur mix is greater than is the case with No. 26—viz: 0.37 as compared with 0.11—and, although the position is not reversed in a "Captax" mix, the curves for August and November rubber are brought very much closer together—vide Figures 5 (a) and (b). In the remaining two estate samples the difference in modulus with a rubber-sulphur mix is much smaller than in the preceding two cases, but the curves for a "Captax" mix are much wider apart. The variations obtained indicate the desirability of expressing the results of vulcanisation tests in terms of a standard technical mix as well as in terms of the usual rubber-sulphur mix. The results are reminiscent of those obtained in the vulcanisations carried out on rubber containing variable proportions of different sugars[2].

As will be seen, the foregoing results are similar to those obtained by Dinsmore[3] an extract from whose article is given below:

"With the object of providing data on variability, rate of "cure was adopted as a criterion and it was demonstrated "that the variation between bales of the same lot of rubber "was as great as the variation between different lots. It was, "shewn that there was also considerable variation throughout "the rubber in a single bale.

"In further tests carried out to determine the efficacy of "blending, tests were made from each of a number of batches "of rubber taken from the breakdown mills. In all, 48 sam- "ples representing 48 batches were taken over a 7 day period "and were studied in a pure gum captax friction, activated "with zinc oxide, with results as follows:—

	Tensile Kg./cm².		700% Modulus Kg./cm².
"24 tests	between 160-180	6 tests	between 140-160
"15 tests	between 140-160	7 tests	between 120-140
"9 tests	between 120-140	18 tests	between 100-120

"This shews a rather wide variation even after blending.

"Another check made to see the effect of using a high "grade tread rubber which had been tested in the friction "formula above, shewed these results on 20 samples.

Friction Test—20 Samples.

Tests.	700% Modulus. Kg./cm².
2, between	160—180
1, between	140—160
10, between	120—140
7, between	100—120

Tread Test—20 Samples.

Tests.	500% Modulus. Kg./cm².
3, between	170—190
9, between	150—170
8, between	130—150

"Point for point there was a general correspondence be-
"tween the high and low tests for the two stocks although
"there were some reversals. Here again the fluctuation is
"considerable. The above data are typical of a large mass
"which, unfortunately, time did not permit of condensing to
"suitable form for this hastily prepared review.

"It is now pertinent to ask whether these results are re-
"flected in any practical performance tests. Two rubbers
"were selected by the friction formula, giving moduli of 120
"and 57 respectively. These were compounded in a solid tire
"stock where the differences were apparently entirely elimi-
"nated. However, on a blowout test, the *high* grade rubber
"gave about *45 per cent. more mileage* than the *low* grade.
"Two other rubbers were selected having modulus figures in
"the friction stock of 147 and 37. Here the solid tire stock
"shewed about 8 per cent. difference in modulus, but there
"was 50 per cent. difference in the mileage to blow out.

"In a high grade balloon tread stock, rubbers which were
"selected because they gave moduli of 104 and 53 in the fric-
"tion test, gave 88 and 84 in the tread stock with abrasion loss
"figures of 10.9 and 11.5 respectively. The road wear resist-
"ance was in the ratio of 112 to 100.

"Another test was made on a pneumatic truck tire carcass
"for blowout. The rubbers tested 105 and 70 modulus. On
"a slow speed there was no difference beyond the experi-
"mental error. The high speed test shewed a difference of
"60 per cent. in favour of the high-test rubber."

Discussion.

While it is recognised that the adoption of rate of cure and tensile strength of the vulcanised rubber may not be entirely indicative of the true characteristics of any particular type of rubber, it is felt that rate of cure and tensile strength of the product provide a very reasonable criterion for determining the uniformity of any particular product, and there has been sufficient work done to shew that the other characteristics of rubber, such as those associated with ageing and plasticity, are subject to the same degree of variability. Investigations on plasticity have been carried out in the Dutch East Indies and by the Rubber Research Scheme, Ceylon. ([5] and [6]).

From these results, it is obvious that in spite of the knowledge we possess and the work which has been done on the preparation of rubber of uniform quality, there is still a very marked variability in the product of even first class European estates. The divergence of the results recorded for plasticity may possibly be accounted for by the difference in age of the samples tested by the two investigators, but it is also open to assumption that the variations originated in the preparation of the samples.

It is thus evident that one must eliminate variables due to methods of preparation before attempting to compare any two kinds of rubber. The extent of the influence exerted by variations in estate factory practice on the rate of cure and tensile strength of the raw product were sufficiently demonstrated as early as 1914 by Eaton, Grantham, and Day[4]. Further investigations carried out along these lines show conclusively that it is possible only by precise control of all the operations involved to produce a raw rubber possessing uniform characteristics. The calibration of variability is a first essential in the examination of rubber from different clones of budgrafted stock and in the comparison of smoked sheet with air-dried sheet.

It is of great significance that, at the present time, when the price of plantation raw rubber is at the lowest level reached since the beginning of the industry, the world consumption of reclaim is yet as high as 36 per cent. of the total.

In other words, although the raw product can compete in price with reclaimed rubber the latter is still very widely used, and there are good grounds for stating that the explanation of this striking fact is that manufacturers find in reclaim desirable properties which are not possessed by plantation raw rubber.

It is outside the scope of this paper to discuss the possibilities of preparing a plantation rubber possessing all the desirable characteristics of reclaim, but it is justifiable, in view of the marked

variation in first grade sheet disclosed by the above results, to emphasise the need for standardising our methods of preparation whereby the uniformity of our product may be more closely related to manufacturing requirements.

From the results published by previous investigators and the results recorded elsewhere in this Journal[2], it has been shown that variability in rubber is caused by the presence of serum substances derived from the parent latex. Therefore, if the product of plantation factories is to be uniform in quality, the proportion of serum constituents present in the rubber must be reduced to a minimum or to a constant proportion. Modern methods of estate factory practice provide means for accomplishing this.

Summary.

An examination of the samples of sheet rubber collected at a recent Exhibition discloses a high degree of variation in the vulcanisation properties of the rubber.

Similar variations in the normal produce of first class estates are recorded. Other properties of rubber such as plasticity, may be expected to show similar variability.

Figures are given to indicate the extent of the irregularities and how they would be reflected in technical mixes.

The bearing of this on the industrial uses of raw rubber is discussed.

References to Literature.

1. Malayan Agricultural Journal Vol. **XV,** No. 8.
2. Journal of the Rubber Research Institute of Malaya, (loc. cit.)
3. India Rubber World, Vol. **79,** March 1929—p. 77.
4. Bulletin No. **27,** Department of Agriculture, S.S. and F.M.S.
5. Causes of Variation in Plasticity, Ceylon Rubber Research Comm., India Rubber J. **77,** 32-6 (1929).
6. Plasticity Determinations in Crude Rubber. VII. Relation between structure and plasticity of rubber prepared in different ways. O. de Vries and N. Beumée-Nieuwland, Arch voor de Rubber Cultuur **13,** 283—353 (1929).
7. The Evaluation of Raw Rubber. G. Martin. Trans. Inst. Rubber Ind. **6,** 299—316 (1930).

APPENDIX.

The following sample of the form of the certificate which is issued by the Institute on samples sent for vulcanisation tests gives a summary of the standards and technique which have been adopted and which apply to the results quoted in the present article.

Certificate of Quality of Rubber.

This certificate is based on the results obtained by the following technique adopted in vulcanisation and testing in the Experimental Vulcanising Laboratory of the Institute.

Mixing. The standard mixing consists of 20 grammes of sulphur and 200 grammes of rubber. Three such mixings are made from the sample and from each mixing 4 equal portions of 40 grammes each are obtained for vulcanisation.

Curing. The mixings are kept for a period of 24 hours, after which they are cured in moulds in a steam autoclave at 149°C using a standard N.P.L. thermometer to control the temperature.

Method of Testing. 24 hours after vulcanisation two rings are cut from each portion of 40 grammes by means of a Schopper ring-cutting machine (rotating knives) giving a ring of 3.80 millimetres width. The average thickness of the ring is obtained by a micrometer screw gauge applied to the uncut test-piece.

The rings are stretched to breaking point on a Scott Rubber Testing Machine which records automatically on a chart the stress/strain relationship for the sample.

Corresponding to each period of cure, 6 rings are tested, and the average of the six results recorded.

Modulus. This is the load in kilogrammes per square millimetre obtained at an elongation of 650 per cent at a cure of 80 minutes. This gives a figure which is used to compare different samples. It is more accurate than the figure for tensile strength at break which is subject to a large experimental error.

Maximum Tensile Strength at Break. The load at break is expressed in kilogrammes per square millimetre. (Kgs/mm^2).

Rate of Cure. This is the period of cure which gives the maximum tensile strength at break.

Experimental Error. The results recorded for modulus are used as criteria for classifying the rubber tested. The actual figures are subject to an experimental error not greater than $\pm$ 4%.

The figures for "maximum tensile strength" are subject to a greater experimental error and should only be regarded as an indication of the normality of the sample.

The results obtained for the samples in this report may be compared with the following figures which are the average values for standard types of rubber examined and recorded in the Institute's laboratory.

Type.	Modulus or Load at 650 per cent elongation at 80 minutes cure. Kgs/mm²	Cure giving maximum tensile strength at break Minutes.	Maximum tensile strength at break Kgs/mm²
Smoked Sheet ...	0.76	80 to 90	1.43
Unsmoked Sheet ...	0.61	90	1.38
No. 1. Crepe ...	0.60	100	1.37
Fine Hard Para ...	0.83	90	1.48

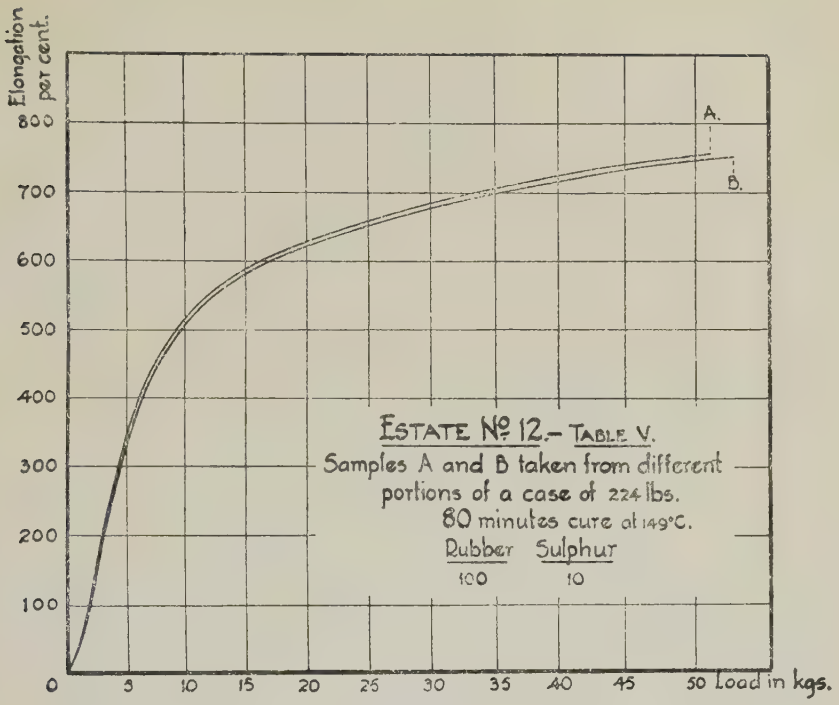

Elongation per cent.
800
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45
50 Load in kgs.
A.
B.
ESTATE Nº 12.– TABLE V.
Samples A and B taken from different portions of a case of 224 lbs.
80 minutes cure at 149°C.
Rubber 100
Sulphur 10

Fig. 1.

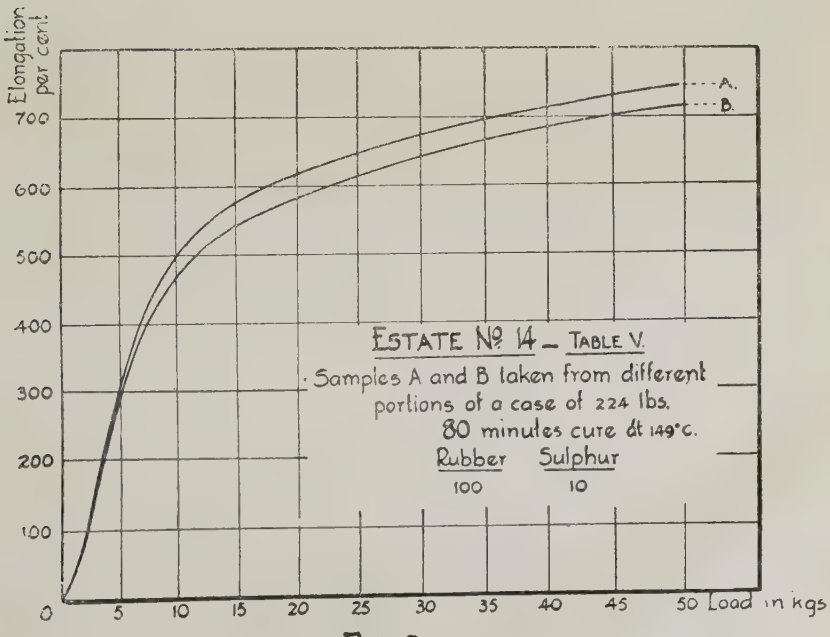
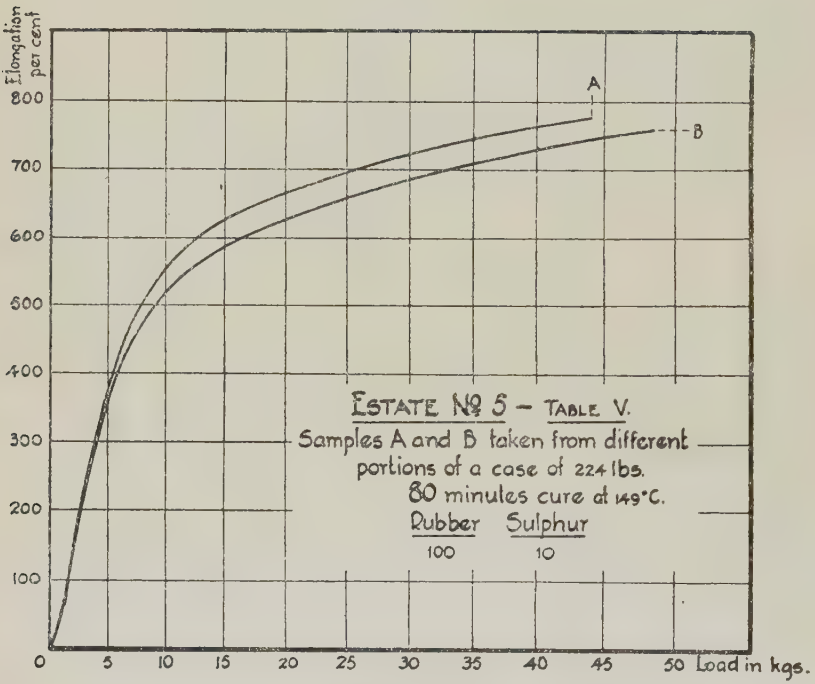

Elongation per cent.
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45
50 Load in kgs
A.
B.
ESTATE Nº 14 – TABLE V.
Samples A and B taken from different portions of a case of 224 lbs.
80 minutes cure at 149°C.
Rubber 100
Sulphur 10

Fig. 2.


Elongation per cent
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700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45
50
Load in kgs.
A
B
ESTATE № 5 – TABLE V.
Samples A and B taken from different portions of a case of 224 lbs.
80 minules cure at 149°C.
Rubber 100
Sulphur 10

Fig. 3.

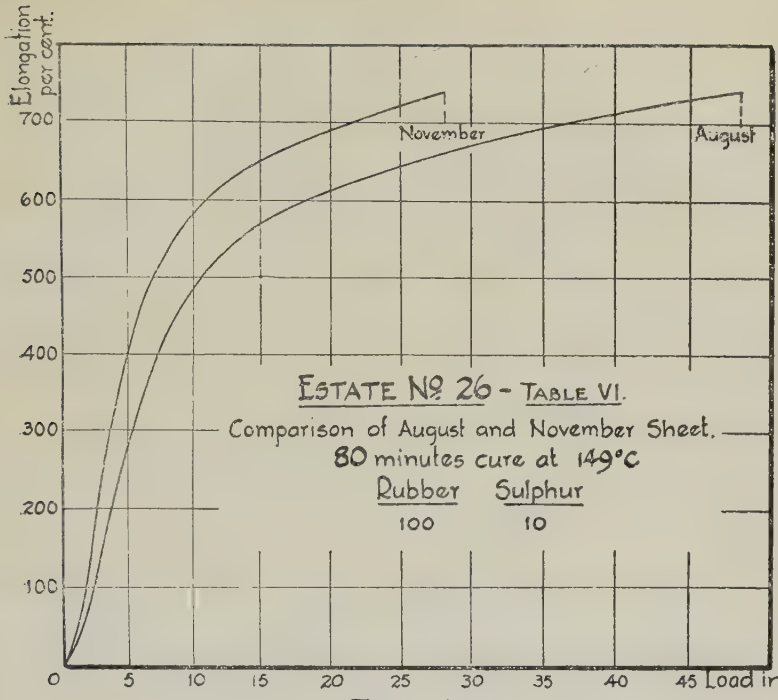
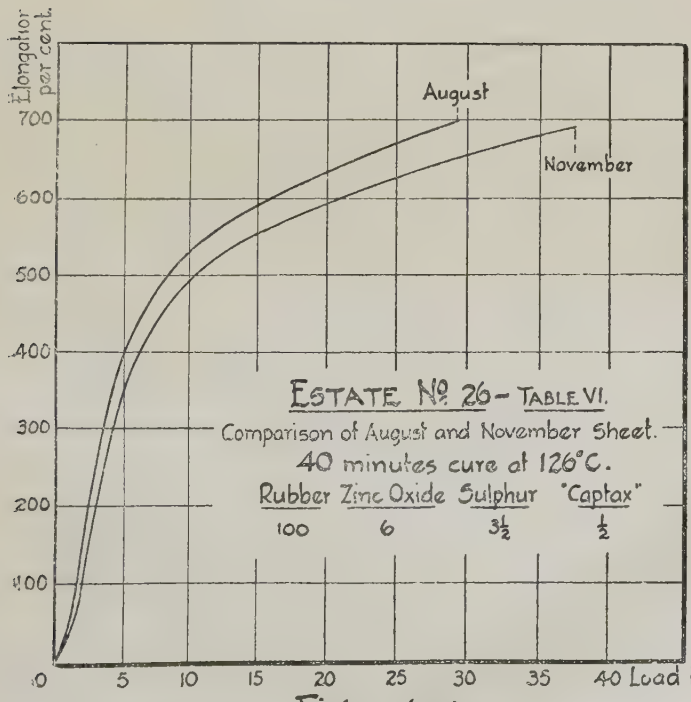

Elongation per cent.
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45 Load in kgs.
November
August
ESTATE Nº 26 - TABLE VI.
Comparison of August and November Sheet.
80 minutes cure at 149°C
Rubber 100
Sulphur 10

Fig. 4(a).


Elongation per cent.
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600
500
400
300
200
100
0
5
10
15
20
25
30
35
40 Load in kgs.
August
November
ESTATE Nº 26 - TABLE VI.
Comparison of August and November Sheet.
40 minutes cure at 126°C.
Rubber 100
Zinc Oxide 6
Sulphur 3½
"Captax" ½

Fig. 4(b).

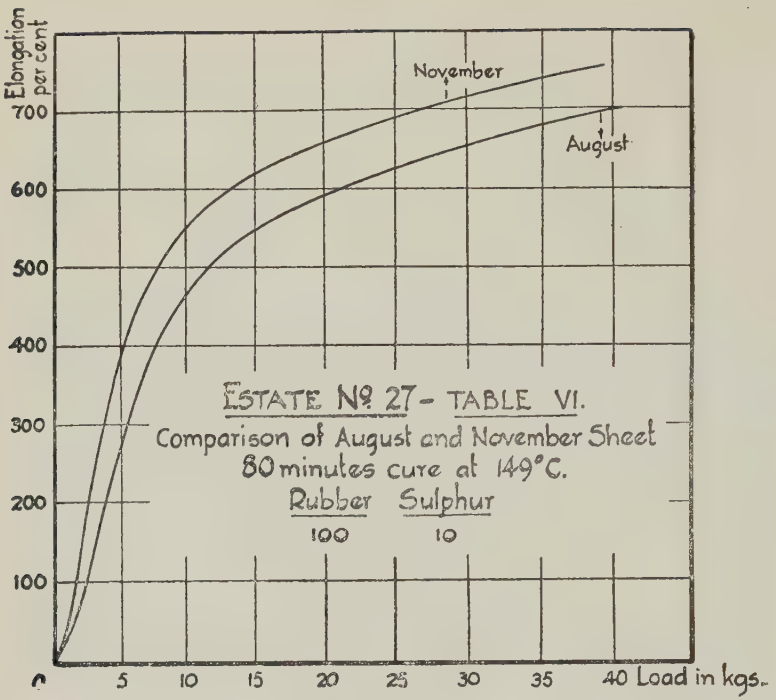
Elongation per cent
700
600
500
400
300
200
100
0
November
August
ESTATE Nº 27 - TABLE VI.
Comparison of August and November Sheet
80 minutes cure at 149°C.
Rubber Sulphur
100 10
5 10 15 20 25 30 35 40 Load in kgs.

Fig. 5 (a).

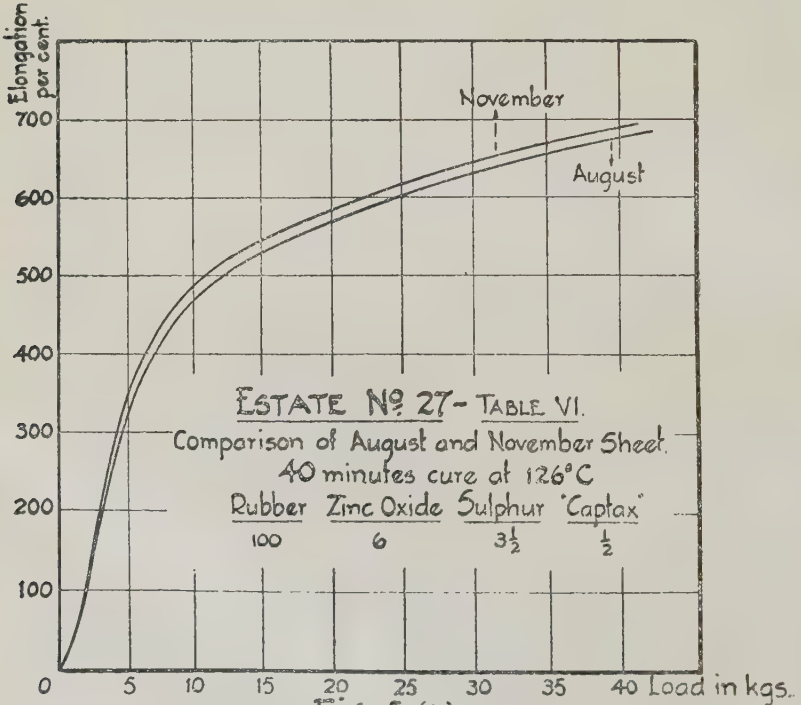
Elongation per cent.
700
600
500
400
300
200
100
0
November
August
ESTATE Nº 27 - TABLE VI.
Comparison of August and November Sheet.
40 minutes cure at 126°C
Rubber Zinc Oxide Sulphur "Captax"
100 6 3½ ½
5 10 15 20 25 30 35 40 Load in kgs.

Fig. 5 (b).

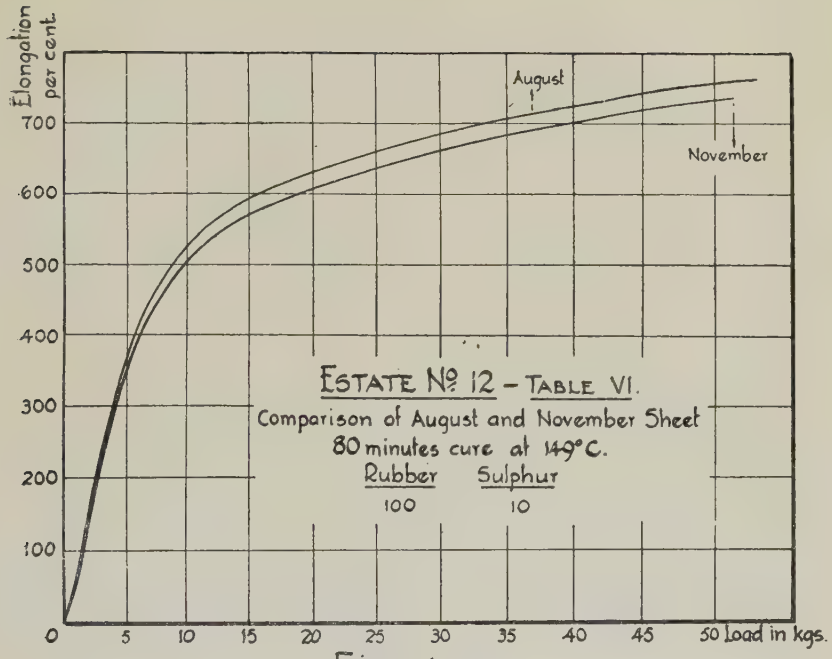
Elongation per cent.
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45
50 Load in kgs.
August
November
ESTATE Nº 12 – TABLE VI.
Comparison of August and November Sheet
80 minutes cure at 149° C.
Rubber 100
Sulphur 10

Fig. 6 (a).

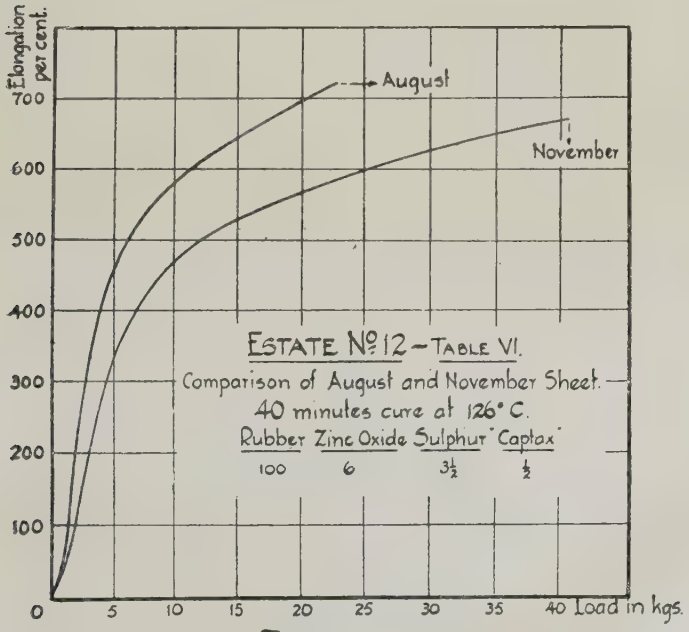
Elongation per cent.
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40 Load in kgs.
August
November
ESTATE Nº 12 – TABLE VI.
Comparison of August and November Sheet.
40 minutes cure at 126° C.
Rubber 100
Zinc Oxide 6
Sulphur 3½
"Captax" ½

Fig. 6 (b).

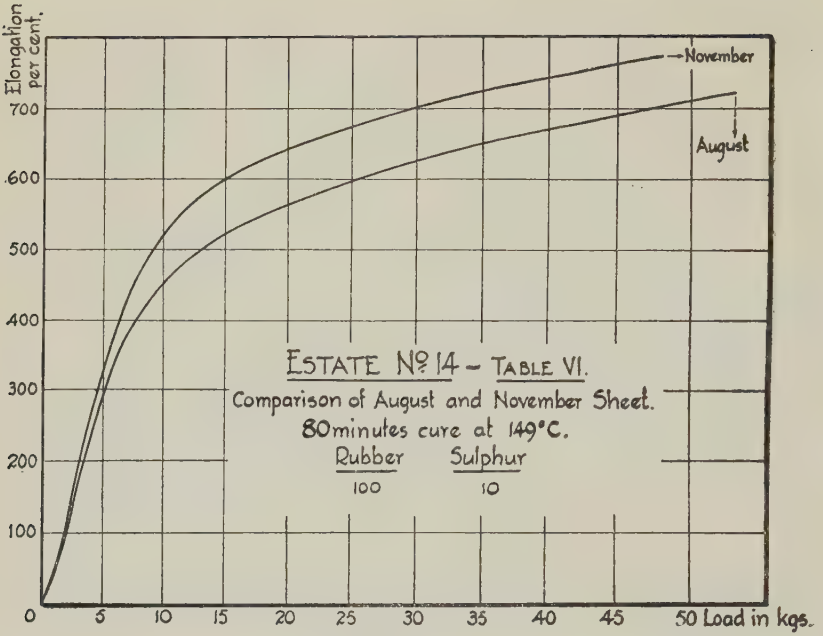
Elongation per cent.
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45
50 Load in kgs.
November
August
ESTATE No. 14 – TABLE VI.
Comparison of August and November Sheet.
80 minutes cure at 149°C.
Rubber 100
Sulphur 10

Fig. 7 (a).

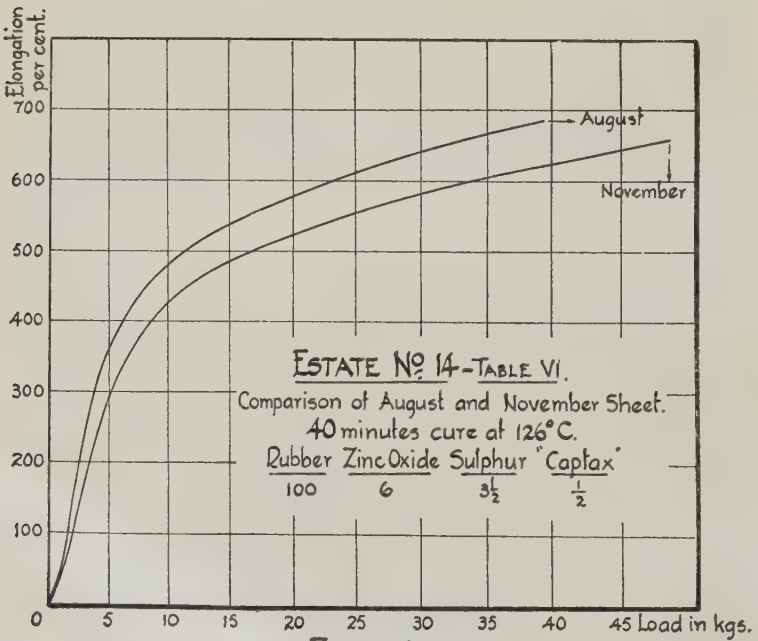
Elongation per cent.
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45 Load in kgs.
August
November
ESTATE No. 14 – TABLE VI.
Comparison of August and November Sheet.
40 minutes cure at 126°C.
Rubber 100
Zinc Oxide 6
Sulphur 3½
"Captax" ½

Fig. 7 (b).

THE EFFECT OF SIMPLE CARBOHYDRATES ON THE VULCANISATION OF RUBBER.

BY

R. O. Bishop and E. Rhodes.

Introduction.

In continuation of investigations on the vulcanisation effects of Hevea Lipin (Quarterly Journal Vol. 2 No. 3) the question arose as to the possible influence of the sugar with which Lipin is known to be associated. The fact that, in spite of the presence of sugars, the behaviour of raw rubber plus Lipin on the mixing rolls is apparently similar to that of raw rubber plus lecithin, suggests that the sugars might be without influence.

While it is recognised that, for the proper understanding of their influence, it is essential to isolate and characterise the free sugars present in latex, it was considered that the vulcanisation effects which we had observed were sufficiently significant in their possible bearing on plantation rubber variation to call for further investigation, and although our subsequent observations cover only a limited field somewhat divergent from the main line of work it appears that the present results are worth recording.

In order to investigate this, mixings were made to determine the effect of the simpler carbohydrates in rubber-sulphur vulcanisates, especially since there are records of the presence of carbohydrates occurring free in latex. (1), (2), (3), (4), (5), (6), (7), (8).

At first the work was confined to mixing simple sugars with plantation rubber on warm rolls.

The mixings were made by incorporating 10 grammes of sulphur with 100 grammes of rubber on rolls at a temperature of about 60°C. The crystalline sugar was added in the required proportion to the plastic mass and the mixing was completed in the ordinary manner. The amounts of sugar added as percentages on the raw rubber are shewn in Table I.

In all cases the mixing proceeded quite normally and there were no signs of the peculiar effects observed when Hevea Lipin is incorporated with rubber. The subsequent testing of the vulcanised mixes, however, gave stress-strain curves which did not coincide with the controls. In almost every case there was

evidence that the added sugar had affected the rate of vulcanisation of the rubber.

Since the results promised to have some significance, further investigations were made. The subsequent observations, although covering only a limited field, appear to be worth recording.

Table I gives the number of minutes of retardation or acceleration of vulcanisation produced by various sugars when mixed with simple rubber-sulphur mixes.

The curves shewn in the accompanying diagrams were drawn by a Scott machine adapted for ring test pieces. For purposes of control, a rubber-sulphur mix without sugar was invariably made at the same time as those containing sugars and test pieces were cured in the same mould and tested at the same time. For this reason the results recorded for acceleration or retardation produced by the sugar are strictly comparable with those of the control sample. All the results recorded refer to this type of control; for example, the retardation of 10 minutes recorded for the mix containing 2 per cent. sucrose and slab rubber H.551/1, was obtained against the control mix of this rubber, mixed, cured and tested at the same time. Specimen curves are shewn in figures I to VIII.

Discussion.

From these results it is evident that the rate of cure of a fast curing rubber (slab rubber) is retarded, while that of a normally slow curing rubber is accelerated, by the addition of small quantities of sugars. These effects are neither uniform nor proportionate to the amount of added sugar. The results do not appear to be related to the constitution of the sugar.

Various authors have recorded the presence in Hevea latex of true sugars as well as quebrachitol, and in view of the amounts stated to be dialysable, it would appear that these sugars are likely to exert some influence on the vulcanisation properties of plantation rubber. The means at our disposal have so far prevented us from confirming the presence of free sugars, but it has been possible to separate quebrachitol by a routine method. Daily supplies of latex from trees of known history have been treated, and the quebrachitol obtained has been bulked and purified. The purity of the preparations has been determined by Melting Point determinations. The material when pure is white and crystal line, has a melting point of 191°C. and does not darken in colour on storage or melting. In order to ascertain the influence of quebrachitol on vulcanisation, mixes of normally fast and slow curing rubbers containing 1, 2 and 3 per cent. of quebrachitol were made in the manner described, together with control samples.

Figure VIII illustrates the results obtained. It will be seen that the results are in complete agreement with those obtained by Stevens H.P. (9) and that the effect of quebrachitol differs essentially from that of the true carbohydrates in that retardation of vulcanisation is produced in all types of rubber and that the effect is approximately proportional to the amount of added quebrachitol.

Having examined the effect of sugars when mixed with dry raw rubber, it was considered advisable to examine rubber prepared from latex to which sugars had been added. For this purpose, aqueous solutions of sugars were mixed with latex immediately before coagulating with acid in the ordinary way. From this latex were prepared both crepe and slab rubber. Control samples of both varieties were prepared from another portion of the same bulked latex to which no sugar had been added. It should be remarked here that, in the earlier work on dry mixes, the slow and fast curing rubbers were prepared from latices which, although coming from the same field, were not necessarily identical in composition.

In the preparations from the treated and untreated latex of the crepe rubber (samples H.584/2, H.551/2 and A.2/1. Table I) the coagulum was machined into crepe within 24 hours after the collection of the latex. In the case of the corresponding slab rubber the coagulum was allowed to mature for seven days before machining. The washing, machining and drying processes were identical.

In every experiment in which sugars were incorporated with latex, the above procedure was adopted and every sample of rubber was compared with a control from a corresponding portion of the same bulked latex. This method was adopted in order to ascertain whether the accelerating or retarding effects of any particular sugar on vulcanisation were influenced by the treatment undergone by the coagulum previous to washing and machining. Figs. VI and VII illustrate the effects produced by the addition to latex of sucrose, dextrose, lactose and quebrachitol in amounts calculated to give one per cent. on the dry rubber content of the latex.

It has been recorded by Gorter (5) that the dialysable sugars of latex may amount to 0.25 per cent. calculated on the latex.

The results obtained are in agreement with those obtained when sugars are mixed with dry rubber, viz. that acceleration of vulcanisation occurs with a slow curing (crepe) rubber and retardation of vulcanisation with a fast curing (slab) rubber when both types are from the same bulked latex. On the other hand, if a fast curing rubber is prepared by dropping latex into alcohol

and rapidly drying the coagulum in thin sheets, the effect of added sugar when mixed with the dry rubber is a definite acceleration in rate of vulcanisation.

The fact that such comparatively inert, nitrogen-sulphur free substances can exert such opposite effects appears to us to be of some importance. It has been shewn that sugars occur naturally in latex and that their amount may vary with the tree and the season of the year(3). Both these factors may therefore affect the quality of the resulting rubber in a manner depending on the method of preparation. There is, at present, no evidence to shew whether the effect of the sugars is achieved directly or through the intermediate action of other substances.

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TABLE I.

Showing minutes of retardation or acceleration effected in the various cures.

Type of Rubber	Mins Cure	Glucose per cent 1	2	3	Fructose per cent 1	2	3	Galactose per cent 0.5	Arabinose per cent 1	2	3	Sucrose per cent 1	2	3	Maltose per cent 1	2	3
Slab (H584/1)	45	+ 5	+ 7	+10				—									
	50	+ 5	+ 5	+ 5				+ 5									
	55	+ 5	+ 7	+ 7				+ 5									
	50	—	—	—	− 7	−10	—	−10	—	—	—						
Crepe (H584/2)	60	−10	−10	−15	−10	−15	−15	−10	—	−20	−15						
	70	−10	−15	−15	−10	−15	−15	—	—	−20	−15						
	20	—	+20	+20	—	+15	—					+ 7	+ 7	—	—	+10	—
Slab (H551/1)	30	+15	+25	+30	+15	+20	+20					+10	+10	nil	+10	+15	+10
	40	—	+25	—	—	—	—					—	—	—	—	—	—
	50	−15	−20	—	−20	−20	—					−15	−25	—	−10	−20	—
Crepe (H551/2)	70	—	−20	—	—	−20	—	(1)	(2)	(3)		—	−20	—	—	−20	—
	30	+20	—	+25	—	—	—	+15	—	—		+ 3	+ 3	+ 7	+15	+15	+20
Slab (L.436)	40	+20	+20	+30	+15	—	+25	+15	+15	+20		nil	nil	+10	+10	+15	+25
	50	+20	+20	+30	+15	—	—	—	—	—		—	—	—	—	—	—
Crepe (L335)	70	—	—	—	—	−20	−25	—	—	—							
	90	−10	−10	−15	—	−20	−25	—	−10	− 5							
Slab (L455)	40	+15	—	—	+15	—	—		+15	—	+10	− 7	—	—	nil	—	—
	50	+15	—	—	+15	—	—		+15	—	+10	− 7	—	—	nil	—	—
Crepe (L458)	70	—	−10	—	—	−20	—		—	−20	—	—	−10	—	—	nil	—
	90	—	−10	—	—	−20	—		—	−20	—	—	−10	—	—	+ 5	—
								Lactose									
Slab (A2/2)	50	+10	—	—				+10	—	—		nil	—	—			
Crepe (A2/1)	80	−10	—	—				nil	—	—		−10	—	—			

(1) A plus (+) sign represents a retardation of vulcanisation and a minus (—) sign an acceleration.

(2) In general, slab rubbers shew a retardation and crepe rubbers an acceleration. The opposite holds in two cases, i.e. slab rubber 455 which is accelerated by 1 per cent of sucrose and crepe rubber 458 which is retarded by 2 per cent. of maltose.

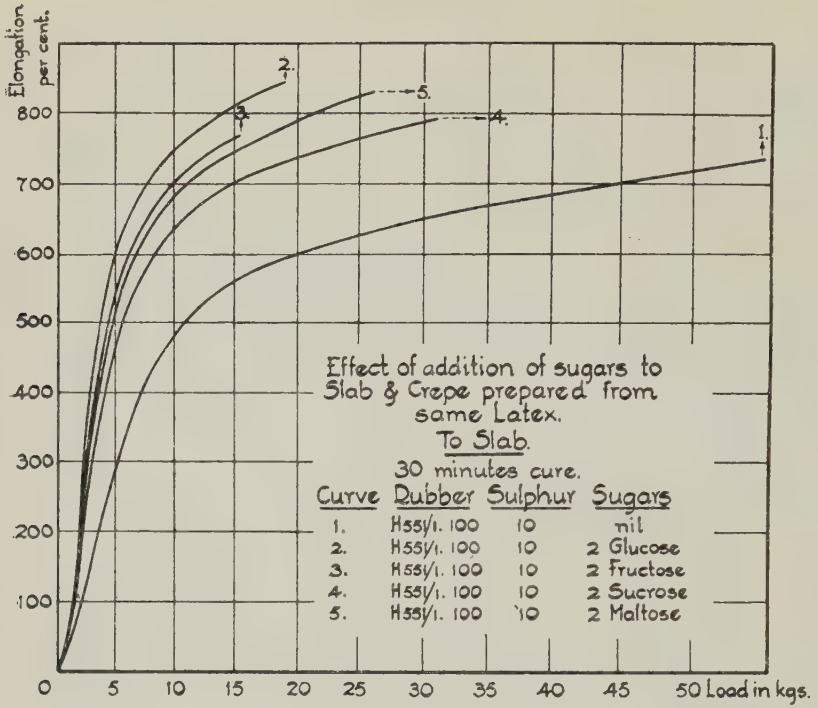


FIGURE I.

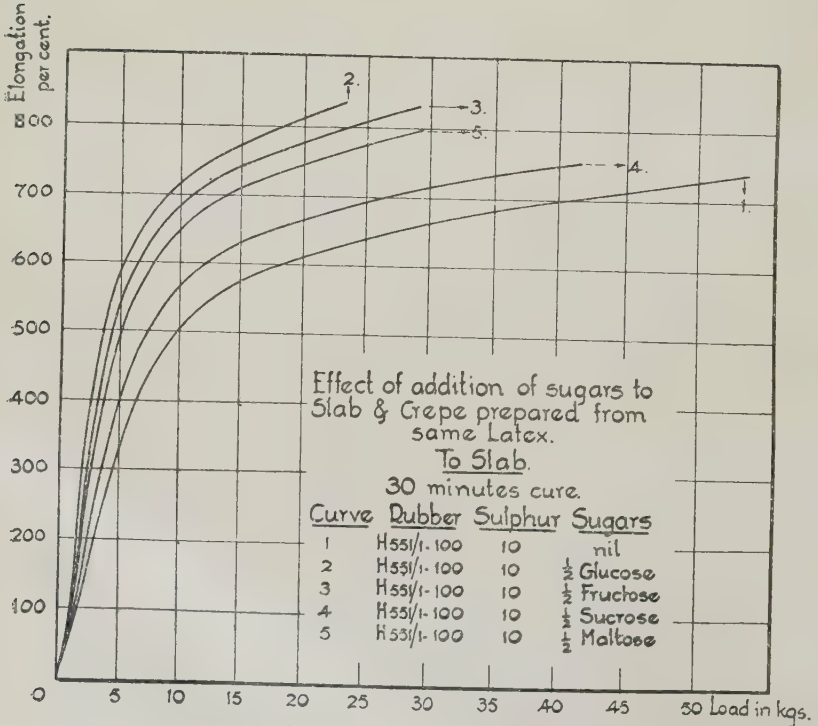


FIGURE II.

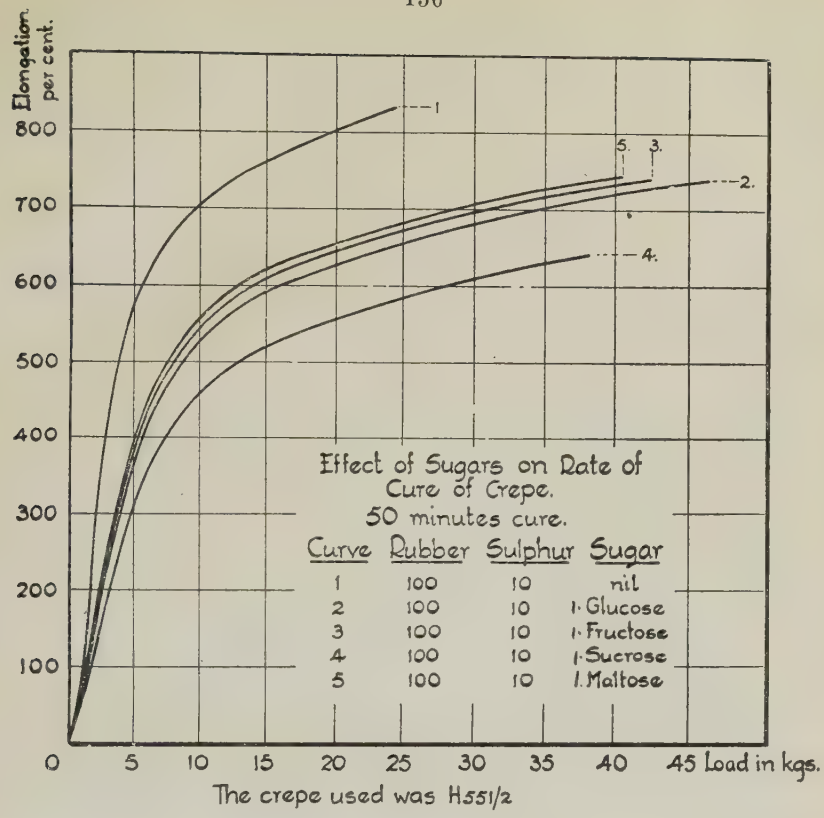


FIGURE III

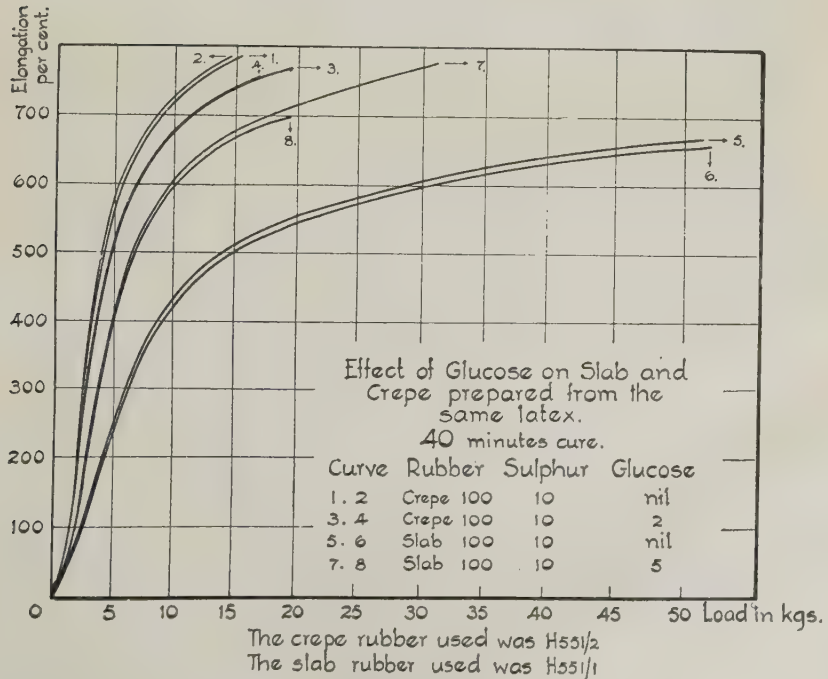
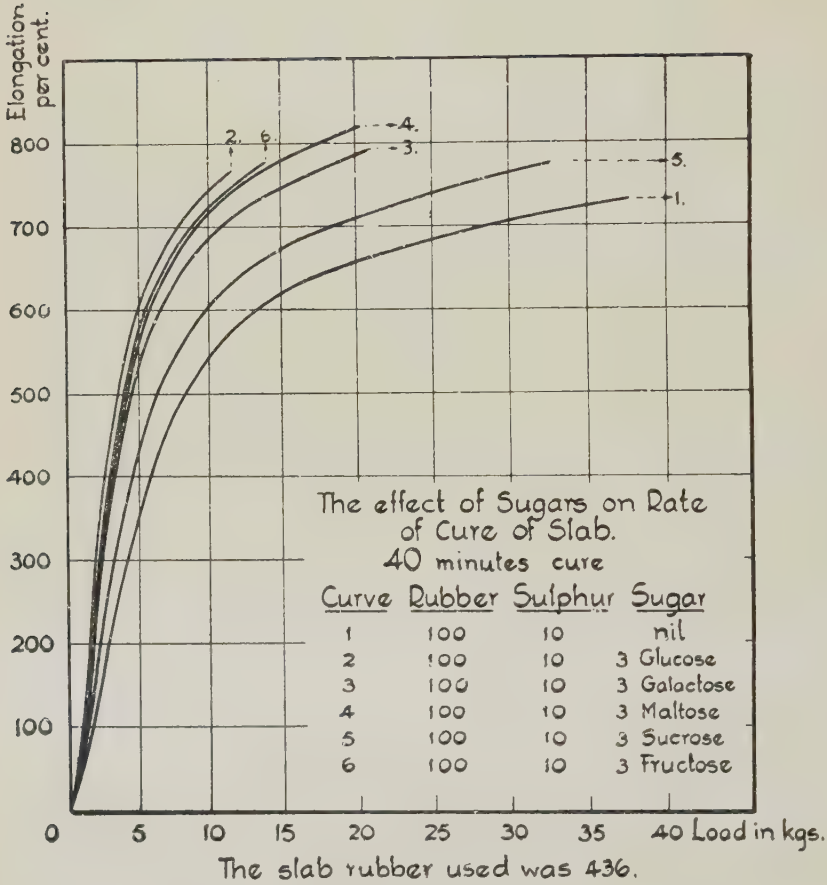


FIGURE IV.



The slab rubber used was 436.

FIGURE V.

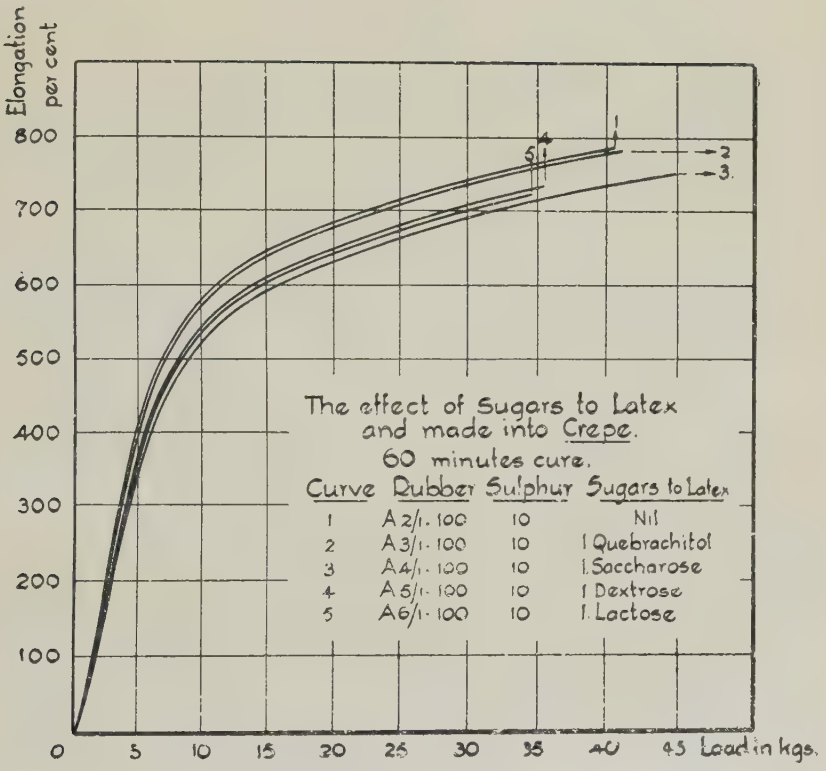

Elongation per cent
800
700
600
500
400
300
200
100
0
5
10
15
20
25
30
35
40
45
Load in kgs.
1
2
3
4
5
The effect of Sugars to Latex and made into Crepe.
60 minutes cure.
Curve Rubber Sulphur Sugars to Latex
1 A 2/1-100 10 Nil
2 A 3/1-100 10 1 Quebrachitol
3 A 4/1-100 10 1 Saccharose
4 A 5/1-100 10 1 Dextrose
5 A 6/1-100 10 1 Lactose

FIGURE VI

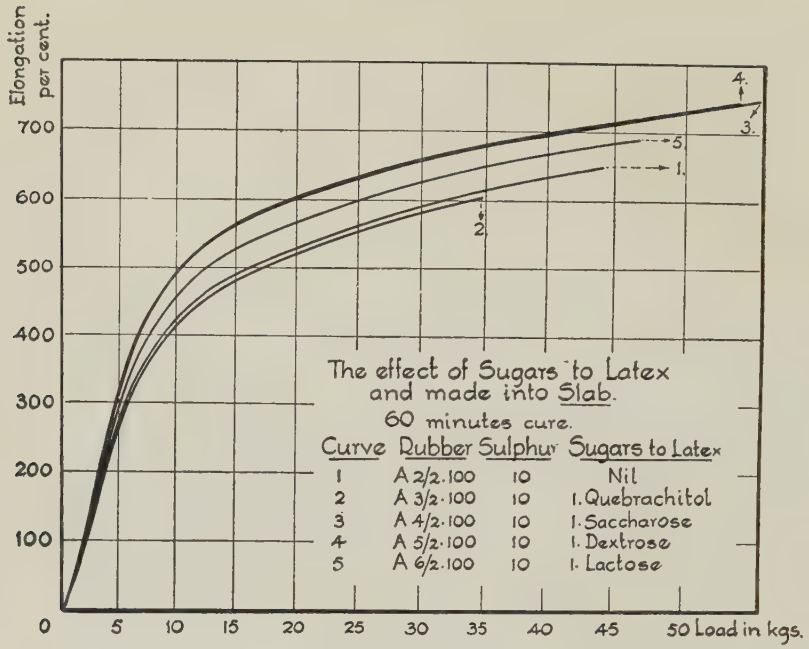


FIGURE VII.

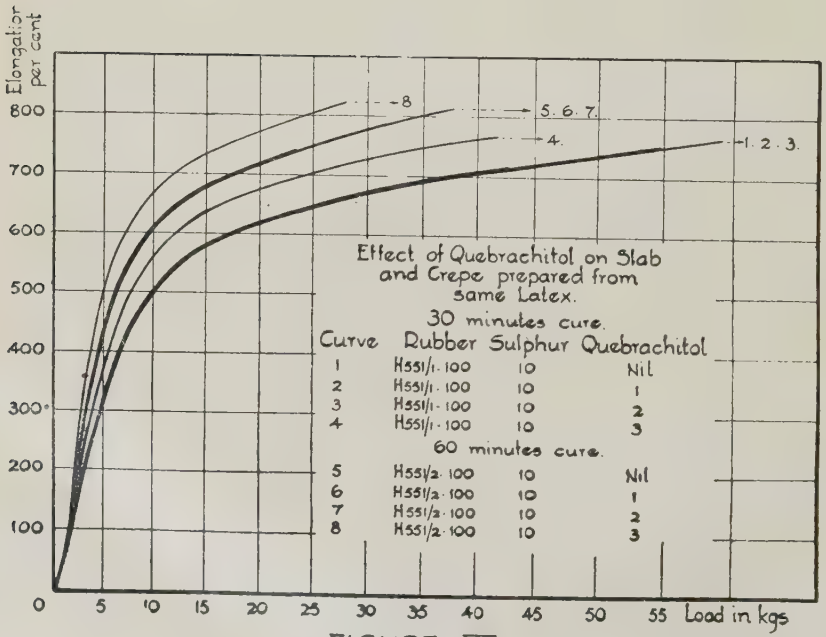


FIGURE VIII.

QUEBRACHITOL—A POSSIBLE BY-PRODUCT FROM LATEX.

BY

E. Rhodes and J. L. Wiltshire.

During the past three years the Chemical Division of the Rubber Research Institute has devoted considerable attention to the non-rubber constituents of Hevea latex, and the possibility of employing these constituents as a new source of revenue for the plantation industry has arisen as a natural consequence of this work. A stage has now been reached when it is possible to report the progress that has been made in this direction with one of the non-rubber constituents, quebrachitol.

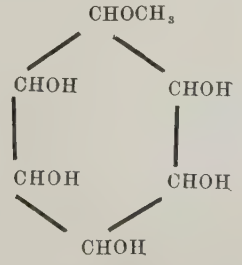
The separation of quebrachitol was an essential portion of our general examination of latex but the extension of this work to a scale considerably larger than that normally employed in the laboratory has had a dual object:—

(1) To obtain figures for the probable cost of production on a commercial scale.

(2) To prepare sufficient quantities of the pure material to enable potential consumers to explore the possibilities of the compound.

The presence of quebrachitol in latex has been reported by several observers and there is an extensive literature on the subject (see bibliography appended.)

Quebrachitol owes its name to its presence in the quebracho bark from which it was first isolated by Tanret in 1887(1). Chemically it is better described as *l*-methyl inositol and has the structure



Published figures for the melting-point vary from 186° to 191° but our experience shows that the pure compound melts fairly

sharply at 191°C. Tanret (loc.cit.) gives its optical rotation for the D line as —80° and its density at 0° as 1.54. The chemistry of the compound has not been by any means fully investigated and the only derivatives to which we have been able to discover any reference are:—

(1) Quebrachi-sulphuric acid and its salts (Tanret.loc.cit.).
(2) *l*-inositol, by hydrolysis of the methoxy group (Tanret. loc. cit.)
(3) penta-phosphoric derivatives (Bruni (2)) and
(4) quebrachityl penta-isovalerate, penta-laurate and penta-palmitate (Levi (3)). Perhaps its most striking property is its very high degree of solubility in water. We have determined the variations of solubility with temperature from 0° to 100°C. in order to effect better control of crystallisation. The results of these determinations are shewn in the graph (Figure 1).
(5) quebrachityl penta-acetate (Contardi, see Levi. loc. cit.)

A point of chemical interest which has emerged in this connection is that quebrachitol is appreciably more soluble than the corresponding unmethylated compound *l*-inositol. Thus at 12°C. the solubility of quebrachitol is about 39 per cent. by weight whereas that of *l*-inositol is only 30 per cent. by weight. This is contrary to the fairly general rule that methylation of a hydroxyl group reduces the solubility of a compound in water e.g. compare methyl alcohol with dimethyl ether and phenol with anisole.

Quebrachitol was first isolated from latex of *Hevea Brasiliensis* by de Jong in 1906 (4). Pickles and Whitfield (5) shewed that it was present both in latex and in rubber either as smoked sheet or Fine Hard Para. They give the total quebrachitol content of the latex as 0.5 per cent. de Vries, in his book "Estate Rubber" (6), reviews very briefly the literature on the subject and states that the amount present in the latex is practically constant at about 1.5 per cent. In another section, however, he states that the content may rise to 2.5 per cent. of the latex. Gorter (7) found 1.5 per cent. and Spoon (8) reports a variation throughout the year from 1.0 to 1.9 per cent. of the serum which is equivalent to approximately 1.5 to 2.5 per cent. of the latex. It will be seen that considerable difference of opinion exists and as many of the observers quote results without describing the method used a reasoned discussion of these divergences is impossible.

At present there is no really satisfactory method for the determination of quebrachitol and we advance the following reasons in support of this statement:—

(1) There is no method of precipitation available.

(2) The optical methods previously employed are invalidated by our lack of knowledge of other optically active compounds which may be present in latex.

(3) The great solubility of quebrachitol in water together with the presence of other soluble compounds such as sugars and potassium salts renders impossible its complete separation by crystallisation. The only figure which can be advanced with any confidence is the quantity of pure quebrachitol which can be prepared from a serum of known antecedents. In our experiments we have obtained a yield of 0.2 per cent. using dilute factory serum, which agrees with the figure of 0.5 per cent. found by Pickles and Whitfield for latex.

There is undoubtedly a small amount of quebrachitol remaining in the mother-liquors which are discarded but the recovery of this additional quantity is certainly impracticable and may be impossible.

In our earliest experiments we followed de Jong (loc. cit.) in obtaining quebrachitol by evaporation of the serum remaining after coagulation of latex with alcohol. The brown crystals thus obtained easily yielded pure quebrachitol when treated with decolourising charcoal in aqueous solution and then recrystallised. In later experiments we used normal serum from acid coagulation and found that the preparation of pure quebrachitol was again a simple operation although requiring rather more care than in the case of alcohol serum. The crystals obtained by cooling concentrated serum were initially separated by filtration and it was found impossible to effect complete removal of the somewhat viscous mother-liquor. Owing to this incomplete removal of the non-crystalline portion, two recrystallisations were necessary to obtain a fairly pure product. This was remedied by the use of a basket-type centrifuge for separation of the crystals from the liquid and the crude product thus obtained was light brown in colour and almost dry (water content 5 per cent.) and yielded almost pure quebrachitol after one recrystallisation only. By the kindness of the Socfin Company and the management of Bungsar Estate we were enabled to evaporate about 2000 gallons of serum and the experience thus gained permits us to put forward a tentative scheme for carrying out this manufacture on an industrial scale.

Raw Material. The raw material for the process is the residual serum from the normal coagulation of latex for sheet or crepe. The serum used in our experiments has been obtained from latex diluted to a content of 1.5 pounds of rubber per gallon, the original content of the field latex being approximately 4 pounds

per gallon. We have obtained a yield of pure quebrachitol equivalent to 0.2 per cent of the serum. In the literature, as previously indicated, are to be found figures which are considerably higher but all our calculations are based on our experimental observations and not on the published figures of other workers.

The quantity of this serum available is assumed to be 1000 gallons per day. A quantity of this order would be produced by an estate with a crop of 90,000 pounds of rubber per month.

Process.

(1) The serum is concentrated by evaporation to approximately one per cent. of its initial volume, the heat-coagulated proteins being removed by skimming.

(2) The concentrate is cooled to 0°C. and is maintained at this temperature until crystallisation is complete.

(3) The crystals are separated from the mother-liquor by means of a basket centrifuge, " whizzing " being continued until no further liquid is ejected.

(4) The resulting light brown crystals are dissolved in water (10 lbs. to 3 gallons) and boiled for 30 minutes with 10 per cent. of their weight of decolourising charcoal. The charcoal is filtered off and the operation repeated. The resulting decolourised solution is evaporated until crystals appear in the boiling solution and then allowed to cool and is maintained at 0°C. for not less than four hours at the end of which time crystallisation is complete. The crystals are separated by centrifuging and, when dried, have a melting-point of 187°—188°C. A further yield of very slightly inferior material is obtained by concentration and crystallisation of the mother-liquor.

(5) The liquid obtained from the centrifugal treatment of the original crude concentrate is evaporated further and allowed to crystallise. This crystallisation is very much slower than the original and it would be probably desirable to investigate the possibility of speeding up this separation by mechanical means. The crude material which is thus obtained is treated as under (3) and (4) above. The relation between the various intermediate products is clearly shown in the flow diagram Figure 2.

Costs.

Evaporation. The following data are assumed:—

Coal.	Cost at factory	$7 per ton.
	Calorific value	10,000 B. Th. Us. per ton.
Boiler.	Steam pressure	60 lbs. per sq. inch.
	Efficiency	60 per cent. (no superheater).
Evaporator.	Triple effect with 90 per cent. efficiency.	

Under these conditions the cost of removing 1000 gallons of water may be taken as $6 for steam alone. Since 1000 gallons of serum yields 20 pounds of pure quebrachitol this is equivalent to 30 cents per pound. From the flow sheet it will be seen that additional evaporation is required in other stages of the process e.g. during recrystallisation. The quantities of water to be evaporated in these operations, however, are very small and certainly do not amount to more than 2 per cent. of the main quantity of 1000 gallons. This figure of 30 cents is therefore taken as covering all the steam requirements of the process.

No absolutely accurate figures are available for the capital cost of the evaporation plant as this depends on the details of the construction and on the cost of transport to the site and of erection. From a study of various figures however it seems that £1,250 may be taken as a probable figure. Capital charges are calculated as 5 per cent per annum interest plus allowance for complete depreciation in ten years. The yearly output of the plant is calculated on the basis that it treats 1000 gallons a day for 47 weeks every year, allowing five weeks for repairs and annual overhaul. This is equivalent to 329,000 gallons of serum and a yield of 6580 pounds of quebrachitol per annum.

The minimum labour requirements of this plant would be three coolies per day, each working an eight hour shift at a minimum daily wage of 40 cents each. The annual labour cost would thus amount to $400.

From this section are omitted three items:—

(1) Water supply.

(2) Capital cost of steam boiler.

(3) Repairs.

The first depends on locality, the seconds depends on the existence or absence of a boiler for other purposes in the factory and the third could only be determined by experience. These figures are therefore omitted on the grounds that any figures advanced would be so tentative as to be useless. The costs under the heading of evaporation may therefore be summarised thus:—

	Per Annum.	Per pound of quebrachitol.
Steam		30 cents.
Capital Charges	$1,590	24 „
Labour	$400	6 „
Total ...		60 cents.

Refrigeration. Several different types of plant are available for this purpose and the cost of the various types might vary considerably. We have been informed on reliable authority that the operation could be satisfactorily performed in an apparatus consisting of an ammonia compression refrigeration machine with brine tanks and insulated vessels for containing the liquids to be cooled, at a capital cost of $1,800 and a daily consumption of two electrical units at four cents per unit. The labour involved in this process would be negligible and the costs may be summarised thus:—

	Per Annum.	Per pound of quebrachitol.
Capital Charges ...	$270	4.5 cents.
Current Consumption ...	$26	0.5 „
Total ...		5.0 cents.

Centrifuging. The costs under this heading comprise:—

(1) Capital charges on centrifuge.
(2) Power consumption.
(3) Labour.

The plant must be capable of treating each day about 140 pounds of crude concentrate and about 30 pounds of recrystallisation liquors. Owing to the necessity of absolute cleanliness when the pure product is being centrifuged it seems essential to instal a large machine for the crude and a small machine for the final product. These machines, complete with driving motors, would cost about £80 and £15 respectively and would require power of three-quarters and one-quarter horse power respectively. The labour charges may be taken as one coolie per day at 40 cents. Allowing 5 per cent. interest on capital, complete depreciation in 10 years and the same working time as previously we have:—

	Per Annum.	Per pound of quebrachitol.
Capital Charges ...	$120	1.5 cents.
Current Consumption ...	$98	1.5 „
Labour ...	$132	2.0 „
Total ...		5 cents.

Recrystallisation. The heat required for boiling and evaporating the recrystallisation liquors is extremely small compared with that required for the initial evaporation and is neglected. The cost

of centrifuging the final product has been allowed for under the appropriate heading and the items remaining to be considered are

(1) Capital charges on two stainless steel crystallising pans.

(2) Cost of decolourising charcoal.

(3) Labour charges.

Two pans of a suitable size constructed of "Staybrite" steel could be obtained for $700 and only half depreciation is allowed for in ten years.

The amount of decolourising charcoal required is 20 per cent of the weight of crude material treated, i.e. approximately 40 per cent of the weight of pure quebrachitol produced. For a yearly output of 6580 pounds, the consumption of charcoal will be 2630 pounds. The price of a suitable charcoal may be taken as £80 per ton, i.e. 30 cents per pound.

The labour requirements may be assessed at one coolie per day, i.e. at 40 cents per day.

	Per Annum.	Per pound of quebrachitol.
Capital charges ...	$70	1.0 cents.
Decolourising charcoal ...	$789	12.0 „
Labour ...	$132	2.0 „
Total ...		15.0 cents.

Details of Costs.

	Cents per pound.	Cents per pound.
Evaporating.		
Steam	30	
Labour	6	
Capital charges	24	
Total		60
Refrigerating.		
Current	0.5	
Capital charges	4.5	
Total		5

Centrifuging.

Current	...	...	1.5
Labour	...	...	2
Capital charges	...	...	1.5
Total	...	...	5

Recrystallising.

Labour	...	...	2.0
Decolourising charcoal		...	12.0
Capital charges	...	...	1.0
Total	...	...	15.0

Total	...	85

Summary of Costs.

		Cents per pound.
Steam	...	30
Current	...	2
Labour	...	10
Capital charges	...	31
Decolourising charcoal	...	12
Total	...	85

It should be pointed out that this figure for the cost of manufacture of quebrachitol is advanced here in a very tentative manner. It is intended merely to serve as a guide to the *order of cost* and *definitely not as an accurate estimate* upon which absolute reliance can be placed and to which a factory should be expected to work with precision. There is no evaporation plant of the correct type in operation in Malaya and estimates cannot therefore be based on observations made under working conditions. Factors which are at present incalculable have been necessarily disregarded. Thus no allowance has been made for repairs and maintenance and no figure can be advanced with any confidence. An estimate has been made for labour costs amounting to 10 cents per pound of quebrachitol produced. Charges under this head, particularly when dealing with native labour can only be determined with certainty as a result of actual practice on a works scale and it may well transpire that labour costs may amount to

20 or even 30 cents per pound thus bringing the total cost per pound of quebrachitol to 95 cents or 105 cents. Again one of the major items, evaporation cost, depends directly on the yield of pure product and an increase in yield by improvement in technique would be capable of effecting a not inconsiderable decrease in production cost. These figures have been based on the use of serum derived from the coagulation of latex of 1.5 pounds dry rubber content per gallon. From serum derived from latex of 2.0 pounds dry rubber content per gallon a higher yield of quebrachitol as a percentage of the serum could be obtained. Owing to the smaller quantity of serum produced in these circumstances and the retention of a higher percentage of the serum in the coagulum it is problematical whether the use of the more concentrated latex would yield as much quebrachitol as the more dilute, but the yield per 1000 gallons of serum treated would certainly be increased.

It was realised at an early stage of this work that evaporation would represent a very considerable proportion of the total cost of producing quebrachitol and attempts were made to isolate the compound by the precipitation of a solid derivative. Unfortunately all efforts in this direction were unsuccessful and evaporation appears to be the only possible method of separation.

The production of quebrachitol is obviously contingent on the creation of a market which will absorb the compound at an economic price and the material produced in our experiments has been devoted to this purpose. Small samples were taken to England when one of us (E.R.) proceeded on long leave and with the assistance of Mr. B. D. Porritt, Director of The Research Association of British Rubber Manufacturers, a number of chemical manufacturers were interested in the subject. During the last two months over ten pounds of the pure compound have been sent to Mr. Porritt by whom it has been distributed to various firms and at least three of these have shewn a very keen interest. We are unable, at present, to indicate for what particular lines of manufacture quebrachitol may find a use but the hope that there may be a market for it does not appear to us to be unreasonable. Two or three scientific workers of established position in the world of research have also expressed an interest in the chemical possibilities of the compound and have been supplied with small samples.

In conclusion it must be pointed out that we are not making a definite recommendation that plantations should engage in the manufacture of quebrachitol. The object of this paper is to report the effort that has been made to create a new

source of revenue from latex, which has so far given the following results:—

(1) It has been shown that quebrachitol can be prepared by a process of not unduly elaborate technique.

(2) Sufficient material has been produced to enable potential consumers to investigate its possibilities.

(3) Contact has been established with potential consumers and interested scientific workers.

(4) The laboratory results have been used as a basis for the calculation of the probable cost of manufacture on a commercial scale. The translation of costs from the laboratory scale to the full scale has been effected on paper only and it must be pointed out that further detailed calculations by professional designers of plant will be necessary before this translation is effected in fact.

The authors' thanks are due to Mr. R. O. Bishop, Head of the Chemical Division, for his interest and advice during the course of this work.

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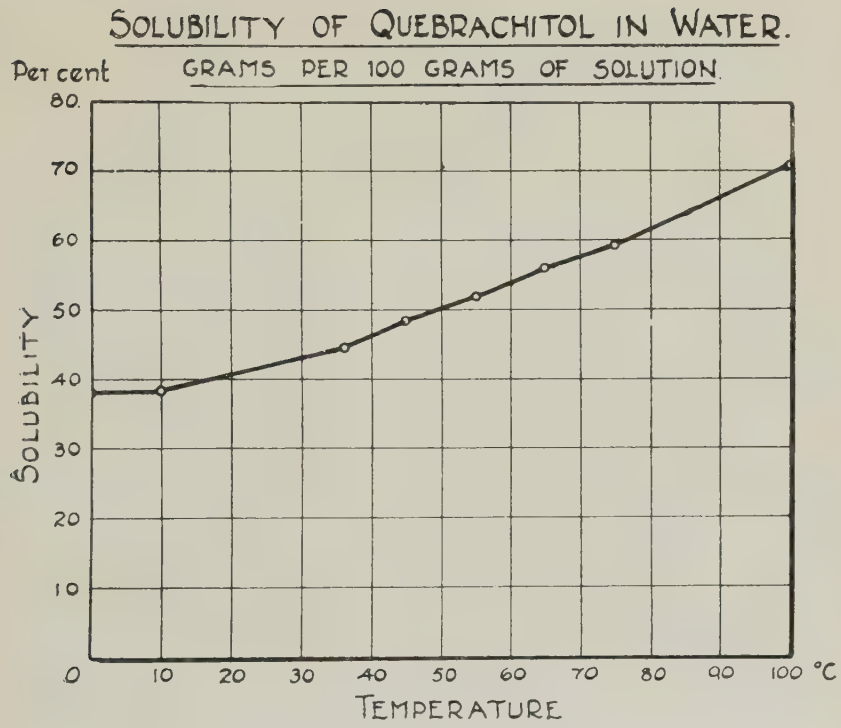

SOLUBILITY OF QUEBRACHITOL IN WATER.
Per cent
GRAMS PER 100 GRAMS OF SOLUTION.
SOLUBILITY
80.
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100 °C
TEMPERATURE

FIG. 1.

FLOW DIAGRAM

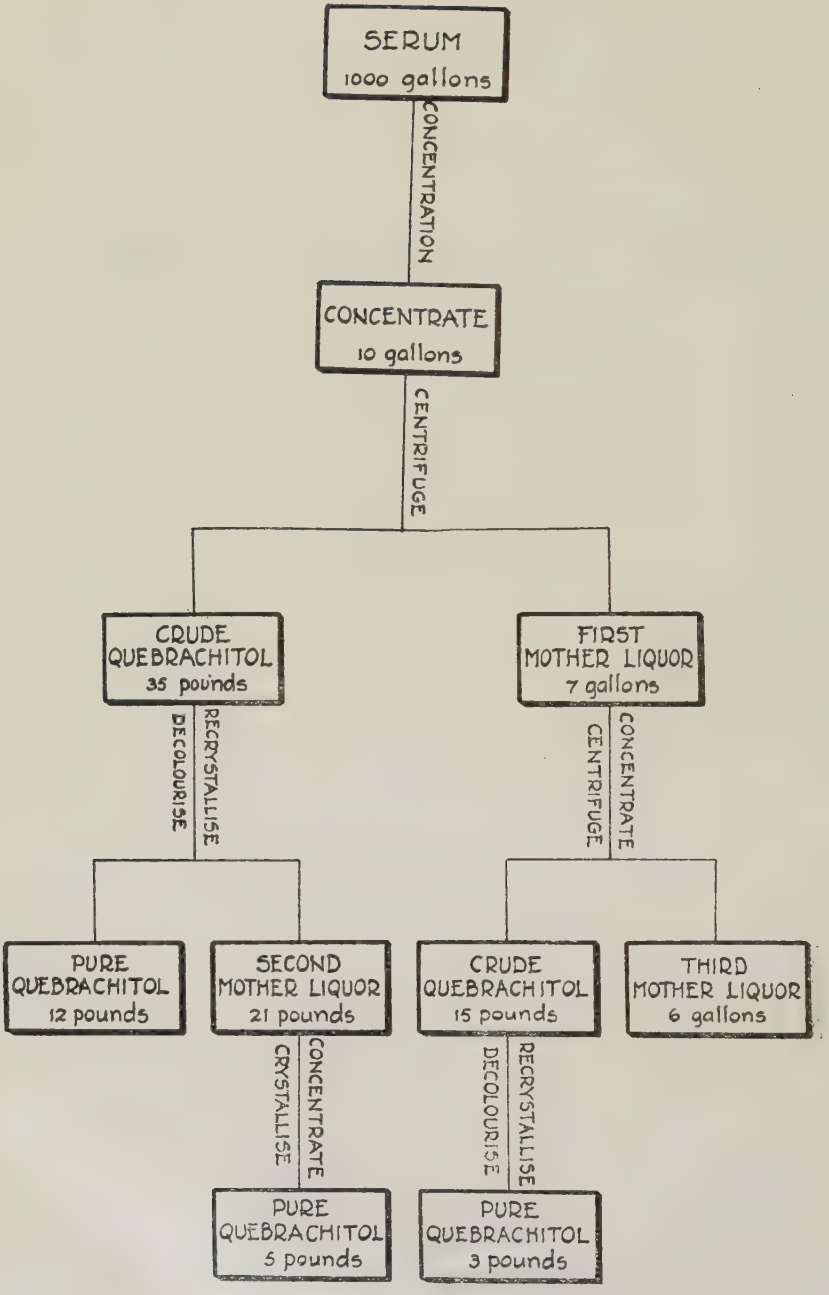


FIG. 2.

OUTBREAKS OF FIRE IN SMOKE HOUSES.

BY

B. J. Eaton.

Considerable correspondence has taken place during the previous year and recently in relation to outbreaks of fire in smoke houses and our advice on the problem has been sought by Insurance Companies, Agents and Managers of rubber estates. Such fires usually result in the complete destruction of the smoke house and contents so that one is only able to theorise on the probable causes.

In the writer's opinion, however, there is little doubt that the principal cause of such outbreaks of fire is the ignition of accumulated inflammable gases which are retained in the smoke house when the ventilation is insufficient.

Inflammable gases may be produced from the wood fuel used in the fire boxes by (a) insufficient ventilation of the fire boxes (furnaces) resulting in dry or destructive distillation of the wood as in the manufacture of charcoal: (b) possible seepage ot water into the fire boxes, such water being converted into steam which reacts on any red hot charcoal producing "water (producer) gas" which is inflammable. The accumulation of such inflammable gases then occurs owing to insufficient ventilation of the smoke house.

Formerly and possibly at the present time on a few estates, charcoal has been prepared in the fire-boxes of smoke houses for use in the producer gas generators used for driving a factory gas engine.

Such a practice should be deprecated since, in the preparation of charcoal from wood, large quantities of inflammable gases are also produced. If the ventilation of the smoke house is inefficient, these gases will accumulate and may be ignited spontaneously by a spark from the fire.

It is suggested that any type of furnace in which the ventilation is poor, resulting in the incomplete combustion of the wood and the formation of charcoal, is a source of danger.

The above is the most probable cause of such outbreaks of fire.

On low lying wet areas, where the fire boxes are constructed below ground level, the second possibility exists, viz. the seepage of water into the fire boxes and the formation of "water or producer gas" by the production of steam and its reaction on red hot charcoal. Some years ago, the writer was asked to report on two such outbreaks of fire in two smoke houses of similar design erected on a flat low-lying coastal estate.

In each case, spontaneous combustion, resulting in an explo-

sion, had occurred, so that nothing remained of the smoke houses or their contents to confirm the theory.

It is also a fairly common practice to dry and smoke virgin scrap and lower grade rubber in smoke houses; in many cases the scrap is spread over the floor of the storey in which the sheet is hung. It has been suggested that such rubber contains inflammable products. This is, however, incorrect. Scrap rubber is similar to sheet and is not more easily ignited. There is however a danger that small pieces of scrap may drop on the fire boxes and become ignited, but this danger is remote.

The spreading of layers of scrap grades on the floor of the storey in which the sheet is hung will however definitely impede ventilation and cause an accumulation of inflammable gases in the lower storey in which the fire boxes are situated. For this reason the drying of scrap in this manner must be deprecated.

The ventilation of a number of smoke houses depends entirely on air which enters and escapes through crevices in the walls and under the eaves of the roof, which is unsatisfactory.

Every smoke house should be provided with suitable inlets for air, near the bottom of the walls and with exit ventilators in the form of a jack-roof or chimney ventilators at the highest point of the roof, so that there is a regular flow of air and combustion gases from the fires, from the lowest to the highest point of the building, with no impedimentation to such flow, except that caused by the sheet rubber which is being smoked.

It is preferable in the first instance to have an excess of such inlets and exits, which can be closed wholly or partially after suitable tests have been made in relation to the rapidity of drying and smoking of the rubber.

In addition, the fire boxes must also be ventilated so that the combustion of the wood fuel is complete but not too rapid.

It appears probable, however, that, sooner or later, smoke houses will be constructed so that the drying of the rubber by heat and the smoking will be separate but simultaneous operations —drying being effected by means of hot water or steam pipes which can be controlled and which results in a great economy of fuel—and smoke, if required, being provided by a separate smoke pot. In such types of houses, hot air-drying without smoking, for the production of air-dried sheet can also be effected. Such a procedure will eliminate fire-risks. Investigations on these lines are in progress. The importance of efficient ventilation of drying and smoke houses, in relation to satisfactory and rapid drying, economy of fuel and reduction of fire risks may be emphasized.

Note:—Since the above was written, a planter has informed us that on entering his smoke house on one occasion, he actually saw a layer of blue flame just below the floor of the second storey.

DESCRIPTION OF SOILS AT THE R.R.I. EXPERIMENT STATION.

BY

C. G. Akhurst and W. B. Haines.

The following notes represent the results of the first attempt at an organised soil survey of the Institute's Experiment Station at Sungei Buloh. Previously, samples had been taken and examined from time to time for special purposes, but field and laboratory work have now been combined to produce a working classification of types and an accompanying map of their distribution.

The main area of the Experiment Station in the Forest Reserve at Sungei Buloh is flat, and is surrounded by slight elevations of one to two hundred feet. The clearing extends on to the lower slopes of these elevations to the east and to the west, as shewn towards the edges of Blocks 15 and 25, and Blocks 22 and 19. One steep hill exists, rising to three hundred and fifty feet in Block 24. Good natural drainage is afforded by two streams which run down the eastern and western boundaries of the present cleared area and join outside the boundary to the south. In the northern Blocks, where the natural drainage has been poor in the past, supplementary drains have been made, as indicated in the map. The soil texture everywhere is such as to permit rapid percolation of water.

The geological formation underlying the area is Quartzite and Shale (Triassic Period), according to the map given by Scrivenor.* This usually weathers to a brown-red clayey sand, showing a great readiness to compact and containing sharp coarse particles of quartz. Soil derived directly from the rock in situ is found only on the hill, the main flat area being covered by transported material of a coarse composition.

Broadly speaking there are three soil types to be distinguished, and their demarcations from one another are very distinct. They are (1) the hill soil, which presumably represents the product from parent rock which has weathered in situ, (2) a detrital soil on the flat which, after deposition, has suffered normal weathering under good drainage, and (3) a modification of (2) on the

* The Geology of Malaya (Macmillan & Co.), by J. B. Scrivenor, 1931.

lower parts of the flat area where poor drainage has led to an accumulation of organic matter. The last type will be spoken of as the swamp type, that term referring to its past history, for it must be understood that at the present time it is well drained. For these areas, therefore, drainage must be reckoned as one of the major alterations in environment produced by the process of opening and planting. In order to compile the required information, soil-profile pits were examined on each of the soil types, and the map of the area was compiled from examination of the surface and of auger borings made to a depth of three feet.

The Hill Soil.

The hill soil is essentially acid (pH 4.5) and sandy (70 per cent. of sand), but it is more compact and has a slightly higher clay content (22 per cent of clay) than the soils on the flat. The amount of clay gradually increases in the lower depths (below 4 feet—62 per cent. of sand; 33 per cent. of clay).

The top layer to the depth of about 2 inches is slightly stained with humus but below this the soil has a uniform tawny yellow colour down to 3 feet. Below this again a faint green mottling and black speckling begins to be noticeable, indicating less well aerated conditions. The organic matter content is surprisingly well maintained, 0.4 per cent. of carbon still being present below 4 feet. The larger quartz stones and particles which are a usual feature are absent in this profile. The nutrient concentrations are normal, and there are no indications that excessive leaching has occurred.

Numerous rock exposures occur on the hill road in Block 24, and these appear to be mainly shales, with some quartzite, being greyish yellow in colour and showing distinct laminations. Several weathered states of this occur—yellow brown and tawny brown sands, with occasional blood red iron concentrations and intrusions of quartz particles.

The Detrital Soil.

This profile shows an open textured acid soil, (80 per cent. of sand, 15 per cent. of clay, pH 4.2), yellow brown in colour, becoming redder below three feet, and of uniform consistency down to about five feet depth. At that depth there is an abrupt change to a heavy white clay (50 per cent. of clay, 40 per cent. of sand, pH 4.0). The content of organic matter and plant nutrients is low and of uniform distribution throughout the profile, which is a state to be expected where water movement is predominantly

downward and excessive in amount. The low concentration of nutrients is partly compensated by the depth of soil which is open to root action by reason of good drainage and aeration.

The detrital nature of this soil type is indicated by its high sand content, by the local topography and by the abrupt differentiation between deposited sand and the underlying clay at five feet depth.

The Swamp Soil.

The northern portion of the clearing lies rather lower and the soil is of the swamp type. One striking characteristic of this area is the large numbers of old termite mounds, which are not found elsewhere. The ants are presumably attracted by the larger amounts of woody material left in the ground and, building their nests above the reach of the water level, work downwards as the seasonal changes in the water level may permit. The original jungle conditions were not a true swamp, but a small stream which for long periods inundated the surrounding land to a shallow depth.

The top two to three feet of the profile are a black humic sand, (carbon 3 per cent, sand 80 per cent, pH 4.7), and below this is a horizon of white, highly leached sand and gravel, in which the concentration of nutrients is very low. The transition between these two horizons is remarkably abrupt. The white sandy layer extends several feet and in places contains a well defined layer of hardpan. Appreciable amounts of nitrogen and phosphorus appear to be combined in the top organic layer (0.15 per cent. N, 0.04 per cent. PO_4). These features have been produced by the site lying under water for a greater part of the time, a condition which leads to relatively slow decomposition of organic detritus and hence to its accumulation.

The bleached lower layer has been produced by the same process as the similar layer in the typical podsol, i.e. by constant leaching with water containing humic acid. In this case the texture is very open which permits of rapid water movement and, from the drainage levels and nearness to the central stream, it is inferred that movement has been largely in a horizontal direction.

In addition to the above three types of soil, there are one or two small patches of an "intermediate" type, which have points of resemblance with both the swamp soil and the detrital soil. There is a slight accumulation of organic matter in the top eighteen inches indicating a certain degree of flooding, but the soil below is the tawny orange sand of the detrital type. No leached subsoil is found.

A hard pan has also been found in places, though its occurrence is so irregular that complete details of its extent are not

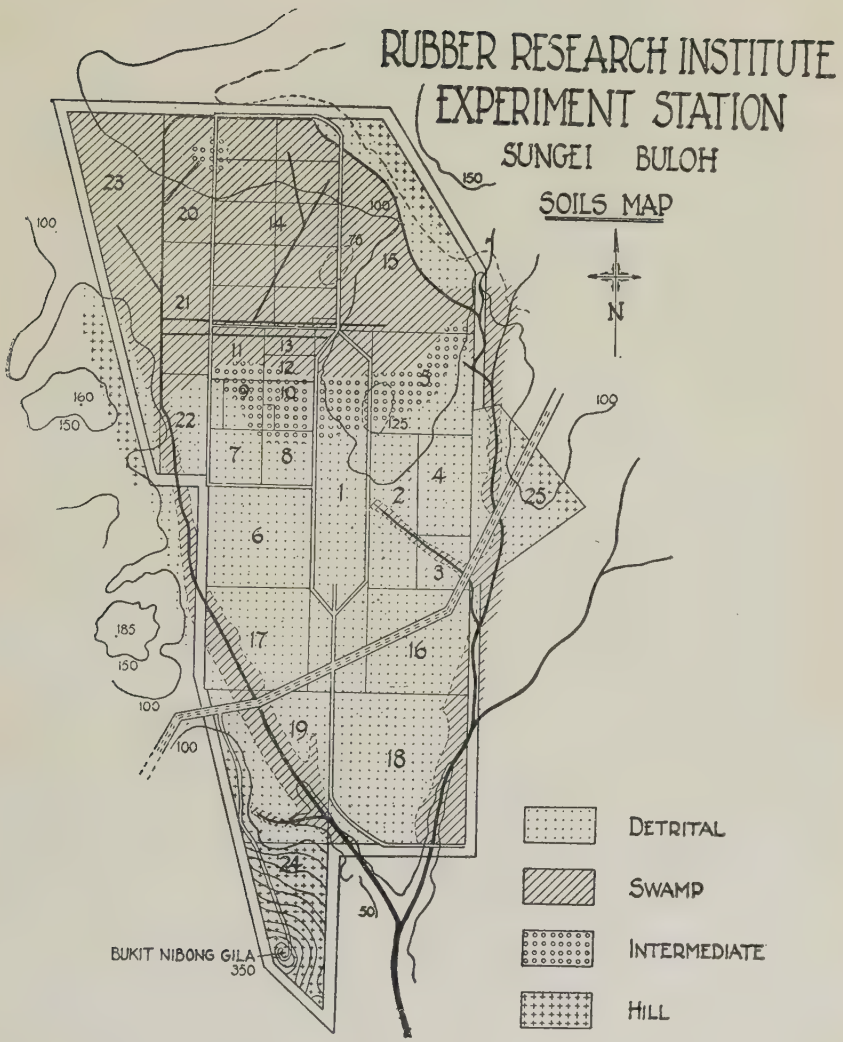
known. It is certainly related to the swamp and intermediate types, and exposures of it were found in two drains—one running north and south between Block 21 (D) and (E) and Block 23, and the other running east and west between Block 14E and Block 11. A red and a black form occur. The former is found about three feet down, underlying a brown sand (intermediate type), and it varies in colour considerably, from a pale yellow to a dull crimson, (the last being very much harder). The black pan is found at five feet depth underlying a top three feet of humic sand and then two feet of leached, white, coarse sand. The cementing agent here seems to be humic material, as a laboratory test failed to reveal the presence of any considerable proportion of iron. The deposition of the hard pan is no doubt an example of the most commonly occurring type, in which the materials dissolved by the humic acid in the percolating water are deposited again at a lower level. The irregular and local character of the pan is to be expected, since the past history of the area will have held many events (exceptional floods, movements due to distant clearing or draining, etc.) which would disturb the exact conditions of the pan formation.

Correlation of Vegetative growth with soil differences.

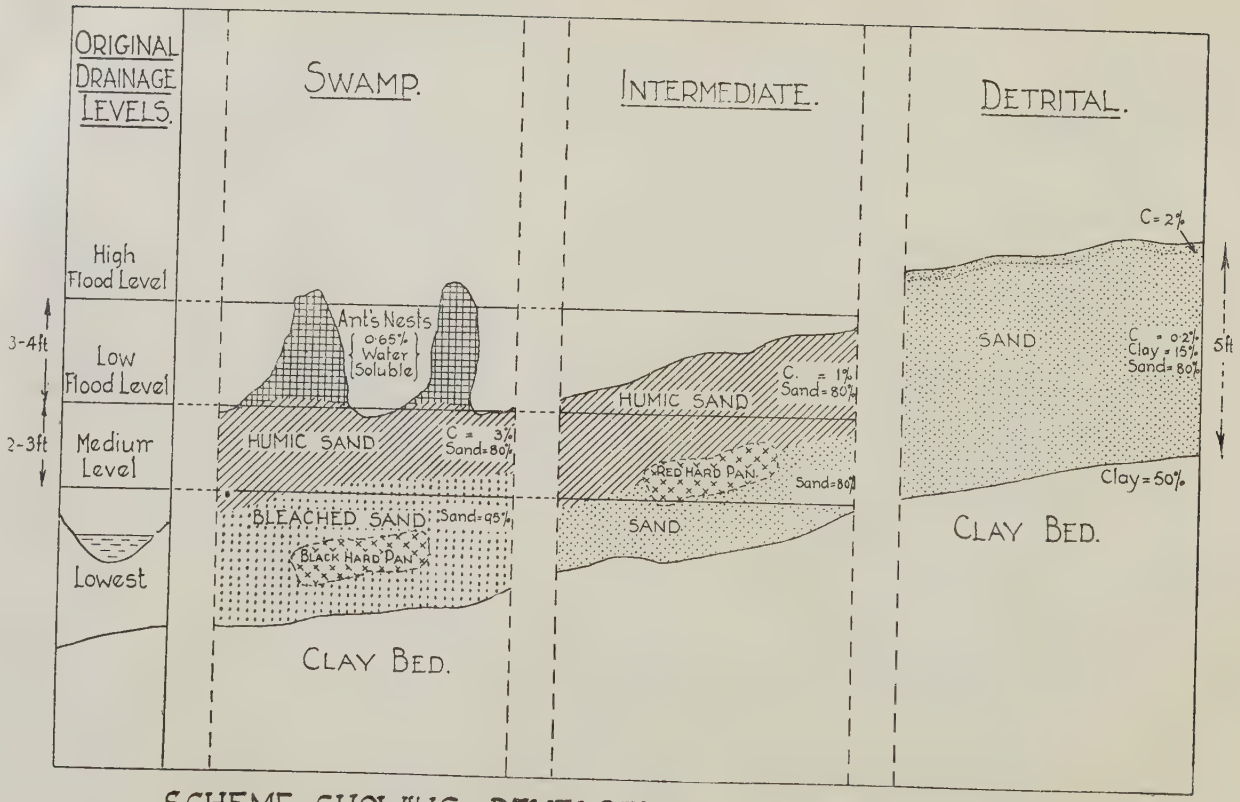
The growth of the rubber trees at the Experiment Station has not yet shown differences which can be definitely ascribed to soil variations. With the cover plants, particularly good growth has been obtained over the swamp soils, whilst on the hill areas it has been poor, but these differences are probably more closely related to water supply than to other soil conditions. For the same reason the rubber trees showed poor growth until their root development made them less dependent upon surface moisture, but after that, growth everywhere has been good. It is concluded that, although some areas have better reserves than others, all areas are at present furnishing adequate available nutrients.

General Discussion.

The question of soil conservation on the hill proved a difficult one for many months after clearing. On the lower slopes contour pits and bunds were put in, and, on the higher and steeper areas, terraces were cut with a steep cant into the hill side. In spite of careful work, constant repair of washouts was required owing to the unusually loose character of the soil. The assistance of covers was also lacking during the early months as no adequate growth was made in spite of careful and repeated planting. This



Note.—The swamp areas after having been drained are all suitable for planting.



SCHEME SHOWING DEVELOPMENT OF SOIL TYPES.

was due to the very dry weather experienced during 1928-29. Conditions have now settled down and no further trouble is being experienced; the porosity of the soil (which is related to its looseness) is proving advantageous rather than otherwise.

The accompanying diagram shows in a highly schematic way the conception we have formed of the relationship of the soils in the flat area. The dominating influence has been the normal fluctuation in drainage levels. Other influences have been the direction and amounts of subsoil water movement, and the tendency for coarser material to form the deposit along the central streams of surface water movement. The higher central portion of the area has stood above the level of any normal flood level. Observations of the wells show that in rainy weather the water table rises to within two or three feet of the surface and sinks to 30 feet or more in dry seasons. The surface layers are therefore well aerated and, in consequence, decay of the surface vegetable detritus has always been rapid. The layer of humic soil is thus only a few inches deep, although a slight humic staining contributes to the soil colour to a considerable depth.

As the soil level falls towards the drainage centres we pass to the intermediate soil type in which there is a greater accumulation of humus due to periods of inundation. The subsoil conditions however, remain similar to the higher areas. Finally at the lowest levels we find a high accumulation of organic material in the surface, with a subsoil of very coarse, highly-leached material—practically a stream bed over which the growth of vegetation has spread and maintained an extra layer.

Although growth on the Experiment Station has been comparatively uniform owing to the freshly cleared state of the soil, there are obviously such differences latent that the future developments and changes under the conditions of cultivation will give scope for many interesting observations and experiments.

Profile descriptions and analytical data.*

1. *Hill Soil profile.*

(Profile No. 10, Sungei Buloh).

0— 2 ins. Very slightly humic, fine sand, tawny orange, numerous roots, compact.

2—12 ins. Campact, tawny-orange sand, uniform colour and texture, few roots.

24—72 ins. Tawny-orange sand, very compact, with pale greenish patching and black speckling, becoming more pronounced towards the bottom of profile.

Analytical data see Table A.

2. *Detrital Soil Profile.*

(Profile No. 1. Sungei Buloh).

0— 2 ins. Humic, coarse sand, fawn-sepia colour, moist, few roots.

2—18 ins. Dirty yellow, brown, coarse sand, very few roots.

18—52 ins. Reddish yellow, brown sand, coarser.

52—57 ins. Hard, cemented, grey gravel; much damper.

57—73 ins. Grey-white clay, with gravel in upper portions; very stiff and dry.

Analytical data see Table B.

3. *Swamp Soil Profile.*

(Profile No. 6. Sungei Buloh).

0—2 ins. Humus material and sand, black-sepia colour, abundant surface roots.

2—22 ins. Brown-black, humic sand, roots plentiful.

Below 22 ins. Coarse, dirty white sand and gravel, very moist, no roots; (below water table level).

Analytical data see Table C.

*NOTE.—The profile numbers refer to laboratory records. Other members of the series taken on typical soils elsewhere in Malaya are to be described later.

Summary.

The topography of the Experiment Station is described and a soil map is reproduced. Three soil types are distinguished and described by means of soil profiles and tables of analysis. The development of the conditions found on the main flat area is explained by reference to a diagram showing the relationship to water levels.

TABLE A.

Sample number	Depth in inches	Loss on evaporation per cent	Loss on ignition per cent	Sticky* point per cent	I. T.	Sand per cent	Silt per cent	Clay per cent	Gravel per cent	Acidity pH Colorimetric	Acidity pH Electrometric	Carbon p.p.m.	Acid extract K p.p.m.	Acid extract PO_4 p.p.m.	Nitrogen	Ratio C/N
S.B. 37	2	0.7	4.9	16.4	2	69.7	4.3	19.7	6.3	5.6	4.29	10,380	1,033	225	749	13.85
S.B. 38	6	0.8	4.8	16.0	2	72.0	4.8	22.4	0.8	5.6	4.53	8,490	497	182	686	12.4
S.B. 39	12	1.0	4.9	15.4	1	73.7	4.6	20.8	0.9	5.6	4.66	7,540	540	165	539	14.2
S.B. 40	24	0.7	4.5	15.0	1	72.3	4.8	22.5	—	6.0	4.82	5,820	494	157	406	14.35
S.B. 41	36	0.8	4.5	15.5	1	70.8	5.0	23.9	—	5.8	4.53	5,580	412	163	511	11.5
S.B. 42	48	0.8	4.8	16.7	3	69.4	4.8	25.5	—	5.5	4.34	5,040	334	165	336	15.0
S.B. 43	72	1.4	5.7	15.9	3	62.8	3.2	33.4	0.6	4.6	4.15	4,010	593	160	280	15.3

* "An Index of Soil Texture," F. Hardy, J. Agric. Sci., 1928, XVIII, 252.

"Sticky Point" is the percentage of moisture in a soil sample in such a state that when kneaded in the palm of the hand it just does not stick.

$$\text{I.T.} = \text{Index of Texture} = \left[\text{Percentage Moisture Sticky Point} - \frac{\text{Percentage of sand}}{5} \right]$$

p.p.m.=parts per million.

TABLE B.

Sample number	Depth of lower horizon	Loss on evaporation	Loss on ignition	Sticky point	I.T.	Sand	Silt	Clay	pH Electrometric	Carbon	Acid extract		Water extract	
											K	PO_4	K	PO_4
	ins.	per cent	per cent			per cent	per cent	per cent		p.p.m.	p.p.m.	p.p.m.	p.p.m.	p.p.m.
S.B. 1	¾	11.9	5.38	18.2	1	85.2	3.2	11.6	3.80	19,380	94	222	34.3	0.49
S.B. 2	1¾	11.9	5.0	16.9	2	75.6	8.0	16.4	4.90	12,390	99	201	31.2	0.41
S.B. 3	4¼	12.2	4.3	17.4	2	77.2	6.4	16.4	4.83	7,590	105	150	30.4	0.28
S.B. 4	8¼	12.4	3.5	17.7	1	82.0	4.9	13.1	4.40	3,240	110	128	69.7	0.26
S.B. 5	13¼	12.4	3.0	15.7	0	82.0	4.9	13.1	4.47	2,430	83	130	79.9	0.24
S.B. 6	18¾	12.7	3.6	16.3	0	78.8	6.5	14.7	4.28	2,430	118	116	53.2	0.31
S.B. 7	26¼	11.8	4.0	15.7	1	74.2	6.4	19.4	4.22	2,280	122	121	22.5	0.27
S.B. 8	35¾	11.0	4.0	15.1	0	77.2	6.5	16.3	4.31	1,170	140	112	39.1	0.36
S.B. 9	44¾	10.5	4.1	14.1	0	77.2	8.1	14.7	4.12	1,200	87	114	25.2	0.24
S.B. 10	52¾	7.6	1.9	12.4	0	83.8	8.0	8.2	4.36	1,200	71	101	34.6	0.47
S.B. 11	57¼	7.3	1.6	13.1	0	74.2	8.0	17.8	4.36	810	97	126	30.5	0.31
S.B. 12	61½	14.6	4.9	22.6	10	63.0	3.2	33.8	4.24	2,340	151	179	22.8	0.63
S.B. 13	73¼	19.3	7.5	28.9	21	41.4	6.6	52.0	3.90	2,820	250	172	28.1	0.24

TABLE C.

Sample number	Depth of lower horizon (ins.)	Loss on evaporation per cent	Loss on ignition per cent	Sticky point per cent	I.T.	Sand per cent	Silt per cent	Clay per cent	pH Colorimetric	pH Electrometric	Carbon p.p.m.	Acid extract K p.p.m.	Acid extract PO_4 p.p.m	Water extract K p.p.m.	Water extract PO_4 p.p.m.	Nitrogen p.p.m.	Ratio C/N
S.B. 31	2	6.6	35.4	40.6	25	75.8	13.7	10.5	5.6	4.42	131,400	319	640	27	2.5	6,580	20.0
S.B. 32	6	3.2	15.3	27.4	12	76.6	13.3	10.1	6.2	4.89	35,460	170	450	34	2.0	2,072	13.0
S.B. 33	11	2.2	14.7	28.7	13	76.9	13.1	10.0	6.2	5.05	27,300	135	420	23	2.5	1,386	19.7
S.B. 34	13	2.4	13.4	27.5	11	82.2	12.8	5.0	5.8	5.05	17,640	238	310	16	1.0	1,050	16.8
S.B. 35	22	3.0	14.3	27.3	11	83.8	9.6	6.6	6.0	5.01	23,220	174	450	12	0.5	1,176	19.8
S.B. 36	Below 22	0.0	0.3	9.7	...	96.4	3.2	0.4	5.8	4.98	1,560	55	100	5	0.2	84	18.6

TABLE D.

	Loss on ignition	Water soluble per cent	Acid soluble per cent	pH Colorimetric	pH Electrometric	Acid extract K p.p.m.	Acid extract PO_4 p.p.m.	Nitrogen p.p.m.	Calcium p.p.m.	Carbon p.p.m.
Ants' nest	17.78	0.65	15.65	5.1	4.15	50	505	1,400	1,400	24,540

PUBLICATIONS.

Publications of the Rubber Research Institute are issued in the following forms :—

(1) *Planting Manuals* appearing at irregular intervals at a price to be fixed for each number.

(2) *Bulletins* appearing occasionally at a price to be fixed for each number.

(3) *Journal R.R.I.* appearing at irregular intervals each year.

All publications will be issued free to those with active rubber planting interests in Malaya.

The following publications have been issued and copies can be obtained on application at the prices given against each

Bank commission should be added to outstation cheques.

(a) Planting Manuals.

No. 1, "Preparation of Plantation Rubber" by B. J. Eaton ...	$2.00
No. 2, "Budding of Hevea in Modern Plantation Practice" by F. Summers ...	$2.00
No. 3, "Plantation Sheet Rubber Manufacture" by R. O. Bishop ...	$2.00

(b) Journal of the R.R.I., Vol. 1, Nos. 1 and 2	$1.00
Separate copies of other numbers ... ... (each)	0.50
(c) Annual Reports from 1928 ... ... „	$1.00
(d) Bulletin No. 1. Natural Coagulation of Hevea Latex by A. S. Corbet	$1.00
Bulletin No. 2. A Study of the effect of Damp Storage on Raw Rubber by B. J. Eaton and R. G. Fullerton	$1.00
Bulletin No. 3. The Root Disease Problem on Old Rubber Areas in Malaya by A. Sharples and A. R. Sanderson ...	$1.00
Bulletin No. 4. Summary of Meteorological Records, Soils Division, by W. B. Haines	$1.00
(e) Information Cards, dealing with various phases of Rubber Estate Factory Practice and Defects in Raw Rubber. Cards—free. Loose-leaf stiff cover in which cards are enclosed in Malaya	0.50
outside Malaya	$1.00